



**MONTGOMERY WATSON**

EPA Region 5 Records Ctr.



228939

November 15, 1999

Timothy J. Prendiville  
Remedial Project Manager  
United States Environmental Protection Agency, Region 5  
Mail Code SR-J6  
77 West Jackson Boulevard  
Chicago, Illinois 60604-3590

Re: Draft Final Arboreal Study Report  
Blackwell Landfill, Forest Preserve District of DuPage County

Dear Mr. Prendiville:

The U.S. Environmental Protection Agency (U.S. EPA) and Illinois Environmental Protection Agency (IEPA) (i.e., the Agencies) provided comments on the May 1999 Arboreal Study Report in an August 16, 1999 U.S. EPA letter. On behalf of the Forest Preserve District of DuPage County (FPD), this letter provides responses to the Agencies' comments and presents the Draft Final Arboreal Study Report.

The original deadline for submission of the Final Arboreal Study Report was September 15, 1999. However, in a September 14, 1999 letter, the U.S. EPA extended the submittal deadline to November 15, 1999 to allow additional time for a further literature review and to perform a supplemental field reconnaissance.

The FPD and Montgomery Watson met with U.S. EPA and Tetra Tech on August 23, 1999 to discuss the Agencies' comments on the Draft Arboreal Study Report. Subsequently, Montgomery Watson requested further clarification of certain U.S. EPA comments during a September 2, 1999 telephone conversation (documented in a September 7, 1999 letter). Additional clarification was provided through personal communication with Tetra Tech EM, Inc. during the supplemental field reconnaissance performed at Blackwell Landfill on September 23, 1999.

In general, the Agencies have requested that the Arboreal Study Report provide greater detail on the FPD's future vegetation plans for the Blackwell Landfill. However, as stated during our August 23, 1999 meeting, the intent of this Arboreal Study Report is to present an evaluation of tree growth on landfills, and to demonstrate that if properly implemented, trees will not harm the integrity of the existing landfill cap at Blackwell Landfill. The report is not intended to provide specific details on future tree planting activities. These details will be developed in a follow up report entitled "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" to be submitted prior to any revegetation efforts. This follow up report will include specific details such as the type and number of species to be planted, and specific forest and meadow/prairie community types. The Draft Final Arboreal Study Report has been revised to clarify the intended process, and to include a general description of the components of the comprehensive restoration strategy, including planting strategy, field verification, woody vegetation implementation, and long-term monitoring.

For your convenience, we have presented below, the Agencies' August 16, 1999 comments on the Draft Arboreal Study Report in bold-italic, and have then summarized our response. A redline/strikeout version of the modified text is provided in Attachment 1. The Draft Final Arboreal Study Report is provided as Attachment 2.

## **IEPA REVIEW COMMENTS:**

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*The IEPA has completed its review of the Draft Arboreal Report for the Blackwell Forest Preserve Landfill NPL site. The IEPA's review comments follow the general format of the Montgomery Watson document.*

*However, before addressing specific items from the document, the IEPA has pertinent regulations pursuant to 35 Illinois Administrative Code, Subtitle G, Part 811 for landfills such as the one in the Blackwell Forest Preserve. In particular, Section 811.314 Final Cover System (Standards for the Final Protective Layer) and Section 811.322 Final Slope and Stabilization (Vegetation) contain requirements that need to be addressed. A brief summary of these regulations follows:*

- *811.314(a): The unit shall be covered by a final cover consisting of a low permeability layer overlain by a final protective layer constructed in accordance with the requirements of this Section.*
- *811.314(c)(2): The thickness of the final protective layer shall be sufficient to protect the low permeability layer from freezing and minimize root penetration of the low permeability layer, but shall not be less than 0.91 meter (3 feet).*
- *811.322(c):*
  - (1) *Vegetation shall be promoted on all reconstructed surfaces to minimize wind and erosion of the final protective cover.*
  - (2) *Vegetation shall be compatible with the climatic conditions.*
  - (3) *Vegetation shall require little maintenance.*
  - (4) *Vegetation shall consist of a diverse mix of native and introduced species that is consistent with the postclosure land use.*
  - (5) *Vegetation shall be tolerant of the landfill gas expected to be generated.*
  - (6) *The root depth of the vegetation shall not exceed the depth of the final protective cover system.*
  - (7) *Temporary erosion control measures, including but not limited to mulch straw, netting, and chemical soil stabilizers, shall be undertaken while vegetation is being established.*

**Response:**

No response is necessary.

**3.0 General Concerns**

*Although there appears to be research that would support your position as stated in the first paragraph of this section, on page 6, the 35 IAC regulations do exist, and you are correct in that their purpose is to protect the integrity of the landfill cap.*

**Response:**

This comment is similar in nature to U.S. EPA Specific Comment #2. See response provided below.

**3.1 Root Penetration**

*In your first paragraph of this subsection, it is stated in the last sentence that, "root penetration of a landfill cap is unlikely." I believe this is in reference to a properly engineered and constructed clay or clay/synthetic barrier, located at a known depth. In the case of Blackwell, it has always been doubtful as to the extent that a properly constructed and compacted clay layer was installed through out the landfill and this report supports that assumption based on the tree root diagrams.*

*Also the trees used in this study were young trees only 10.5 to 15.0 feet in height. These trees would be expected to have a shallower root system.*

**3.1.2 Soil Compaction Within the Root Zone**

*Soil compaction across the landfill and at various depths is known not to be uniform. Even in those areas where a "clay" barrier may exist, the compaction amounts vary considerably. The landfill studies referred to had a known thickness of clay for a barrier, at a known depth, and apparently with a known compaction amount or proctor percent age. For Blackwell, this is not the case for the majority of the landfill cap. However, it is known that many areas of the landfill cap contain a considerable depth of cover material over the areas of the "clay" layer component of the cap. In these areas of the cap, the use of trees would appear to be less of a problem if the landfill slope is appropriate too.*

**Response:**

The majority of these two IEPA comments refer to the nature and extent of the clay cover over the Blackwell Landfill. However, the FPD and Montgomery Watson previously conducted field investigative studies on the landfill that indicated that a clay cover, meeting agency requirements, was present over all but four areas of the landfill. The clay cover in these four areas was repaired in 1997 and 1998. Details of the field studies, cap repair activities, and subsequent operation and maintenance (O&M) activities confirming that the clay cover is present over the Landfill are provided in the following reports:

- Technical Memorandum on Predesign Investigation (Montgomery Watson, January 1997);
- Cap Repair 100% Design (Montgomery Watson, June 1997);
- Revised Predesign Report (Montgomery Watson, July 1997);
- Final Operations and Maintenance Plan (Montgomery Watson, February 1999); and
- Final Construction Completion Report (Montgomery Watson, August 1999).

The remaining comments are similar in nature to U.S. EPA General Comment #1 and Specific Comment #12. See responses provided below.

### 3.2 Windthrow

*Trees with shallow root systems are more susceptible to windthrow than those trees with deeper roots. Trees that may be overtopped and uprooted would could cause considerable damage to their particular area of the cap.*

### 3.4 Case Studies

*On page 11, top of the page the first paragraph states that the 30 specimens all had shallow root systems. Would not windthrow be of concern for the trees with shallow root systems.*

#### Response:

These comments are similar in nature to U.S. EPA Specific Comment #12. See response provided below.

### 6.3 Suitable Grass Species

*In the second paragraph on page 22, the first sentence states, "The recommended grasses for the Blackwell Landfill are Native Prairie species." Although the IEPA landfill regulations listed above require a mixture of native grass species, the species chosen should also consider root depth. Some native prairie grasses are known to have very deep roots, however, due to Blackwell's extensive depth of soil cover materials in certain areas of the landfill, the use of native grasses should not be a problem.*

#### Response:

This comment is similar in nature to U.S. EPA General Comment #3. See response provided below.

## **U.S.EPA COMMENTS: General Comments**

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1. *Section 3.4. This section provides case studies indicating that the tree root system has the ability to adapt to limited soil cover and an underlying compacted clay barrier. Although the case studies selected adequately show that trees can be sustained under these conditions, they represent short-term studies of smaller, less mature trees than those that may be present at the Blackwell site over the long term. Furthermore, a more appropriate focus of the case studies would be to discuss whether the integrity of the cap can be maintained while the trees are sustained. If available, additional, longer-term studies providing information on the impact of woody vegetation, including mature and "native" trees, on cap integrity should be provided. Available information regarding how the density of tree planting affects this impact should also be included.*

**Response:**

Additional case study information has been added to Section 3.4 regarding the height, age, and planting density of tree and shrub species planted, when available. However, we have been unable to locate additional case histories that provide longer-term studies on the impact of woody vegetation on cap integrity. Therefore, we have expanded Section 7.3.4, Long Term Maintenance and Monitoring, to acknowledge this information gap, and to reiterate that regular assessments of cap integrity must be performed at 5-year intervals.

More Spec. on  
what will be  
Assessed →

2. *Section 5.1. This section states that the soil conditions at the Blackwell site do not pose a problem based on the number, variety, and relatively healthy appearance of trees on the landfill. However, this statement generalizes the conditions on the landfill, which appear to vary considerably based on the apparent variation in the distribution of trees on the landfill. Additional justification for the evaluation of soil conditions across the entire landfill should be provided.*

**Response:**

Sections 5.1 and 5.2 of the Draft Final Arboreal Study Report provide qualitative assessments of soil conditions, including aeration, soil fertility, soil moisture content, temperature, and the effects of leachate and landfill gas, on vegetation growth on the Blackwell Landfill. Quantitative factors, including but not limited to, root zone depth, soil nutrients, and differences in slope and sun exposure, will be evaluated by an ecologist as part of "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" that will provide details of the woody vegetation management plan. Details of this follow up report are provided in Section 7.0 of the Draft Final Arboreal Study Report.

Shouldn't that  
be done up front  
to provide framework  
for what plants might  
work.

3. *Section 6.3. This section identifies prairie grasses and wildflowers as being suitable for the Blackwell site. However, the roots of prairie plants often extend*

*much deeper than 2 feet into the soil. For example, the roots of big bluestem and switchgrass may be more than 7 and 11 feet deep, respectively. Furthermore, prairie plants require fire as an important part of their ecosystem. The text should be revised to evaluate the potential impact of the proposed prairie plants' roots on the integrity of the landfill cap, the suitability of landfill soil conditions for the growth of prairie plants, and the feasibility of using fire as a prairie management tool on a landfill where flammable gases such as methane diffuse through the cover.*

**Response:**

We agree that under ideal circumstances, the rooting depth of prairie plants may be several feet deep. However, the clay cap will act as a barrier to deflect root growth from vertical to horizontal. This being said, we have modified Section 6.3 of the Draft Final Arboreal Study Report to add a statement that the rooting depth of prairie plants may be several feet deep, and that long term monitoring of potentially deep rooted prairie plants is required.

Provide Spec. on  
Monitoring

Section 7.3.1 of the Draft Final Arboreal Study Report discusses current controlled burn practices employed by the FPD including safety actions which may be undertaken due to protect landfill gas venting, leachate extraction, and monitoring systems on the landfill.

4. *Section 6.4. This section identifies the "native" trees that were judged as being suitable for the Blackwell site. To justify the selection of these trees and to provide a more appropriate, longer-term restoration strategy, the text should be revised to specify the forest community types or successional stages to which these trees would apply and that could be successfully maintained at the site, as well as how the community types will meet land use objectives. These community types, rather than individual tree species, should be the basis for the woody vegetation strategy for the site and should be reflected in Section 7.0, Protocols for Woody Vegetation Expansion. Also, some of the "native" trees such as oak and hickory species tend to possess the deeper taproot that is not typical of the species chosen for the root penetration study. Therefore, additional information regarding the potential for root penetration of the "native" tree species should be provided.*

**Response:**

The purpose of the Arboreal Study is to present an evaluation of tree growth on landfills, and to demonstrate that if properly implemented, trees will not harm the integrity of the existing landfill cap at Blackwell Landfill. However, we agree with the U.S. EPA Comment and a specific end use scenario with forest community types and successional stages will be provided in "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill", as described in revised Section 7.3.

THIS →  
Supported by  
information from  
OTHER Landfills.

We also agree that under some circumstances, trees can possess deep taproots. However, a compacted soil layer, such as a clay cover, will deform and deflect the taproot, as described in Section 3.1 of this report. In order to confirm the future

integrity of the clay cover, we have stated in revised Section 7.3.4 that long term monitoring of root growth will be necessary.

5. *Section 7.3. This section provides the restoration strategy for establishment of woody vegetation at the Blackwell site. Although it may not be appropriate at this time to specify planting locations for individual grass and woody plant species, general areas for the planting of the proposed habitat or community types should be identified. For example, the following items should be shown in a figure: proposed key areas for removal of unsuitable vegetation, proposed Eurasian meadow and native prairie areas, specific forest community types and associated trees proposed to be planted in each of the four woody vegetation areas, and approximate buffer areas around landfill structures and equipment. The scale used in Figure 4 would be appropriate for displaying this information at this time. In addition, specifics regarding how "relatively young and small" trees will be at the time of planting should be provided. For details that cannot be specified at this time, an outline of a subsequent more detailed restoration plan that describes what the plan will contain should be provided.*

**Response:**

As stated in the Response to General Comment #4, the purpose of the Arboreal Study is to present an evaluation of tree growth on the integrity of the existing landfill cap at Blackwell Landfill. In addition, based on evaluation of the depth of cover soil, Figure 4 of the Draft Arboreal Study provided four distinct areas which are currently suitable for woody vegetation implementation. Because a specific end-use scenario has not yet been chosen, the FPD is not yet prepared to select specific planting locations for individual grass and woody plant species, proposed Eurasian meadow and native prairie areas, specific forest community types and associated tree species in these four areas. These details, including the age and height of the trees at time of planting, will be provided prior to woody vegetation implementation and will be described in greater detail in the "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill." The contents of this report are described in Section 7.3 of the Draft Final Arboreal Study Report.

6. *Section 7.4. This section discusses the protocol for long-term management and monitoring of vegetation at the Blackwell site. Details should be provided regarding how prescribed burns (if they are feasible) will be implemented considering the potential hazards associated with methane gas at the landfill (see General Comment No. 3). Also, maintenance requirements for planted trees, such as watering and pruning, should be discussed. In addition, as part of the regular assessment of the restoration strategy for the site, a long-term monitoring approach should be presented that ensures the integrity of the landfill cap will not be damaged by root penetration or changes in the soil profile associated with prairie plants and woody vegetation, or burrowing animals that may be attracted as part of the restoration.*

**Response:**

The Comment is noted and expanded text on the use of controlled burns is provided in Section 7.3.1 of the Draft Final Arboreal Study Report. This revised section discusses standardized procedures, a health and safety plan, and a contingency plan for conducting controlled burns at Blackwell Landfill. An Internet citation is also provided in the Reference section, providing information on the burning policy.

In addition, Section 7.3.4 of the Draft Final Arboreal Study Report has been modified to provide a more detailed description of a long term monitoring program to be followed after woody vegetation implementation at appropriate areas of the Blackwell Landfill (i.e., those with 2-feet of vegetative cover). The monitoring program is described as a three-phase approach, including regular maintenance, periodic evaluation at five-year intervals, and documentation of clay cap integrity and vegetation performance.

**U.S.EPA COMMENTS: Specific Comments**

1. *Section 1.1.3, Page 3, Paragraph 2, Second Bullet. The text states that additional chemical data was not collected as part of the arboreal study effort because a site reconnaissance indicated that the existing chemical profile of the cover soils was already permitting healthy tree growth. However, this assessment is qualitative in nature and apparently does not consider a control group of similar-age trees of the same species as those present on the landfill. Furthermore, unlike some of the "native" species such as oaks that are proposed as being suitable for the landfill in Section 6.4, the species currently growing on the site are fast-growing, early-successional trees that may be less susceptible to chemical contaminants. Therefore, if implementation of the woody plant strategy continues, further evaluation of the soil chemical profile may be required to evaluate its potential influence on root distribution and rooting depth for the proposed "native" tree species.*

**Response:**

The Comment is noted and we agree that the assessment of the existing chemical profile of the cover soils is qualitative in nature. We also agree that further evaluation of the soil chemical may be required, if deemed necessary by an ecologist, prior to implementation of woody vegetation on Blackwell Landfill. A more detailed discussion of soil chemical profile testing will be discussed in "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill."

Why not now.  
Would answer  
A lot of questions

B: EPA, New Chemicals to be added

EPA

2. *Section 2.0, Page 5, Paragraph 4. This paragraph states that the maintenance of woody vegetation at the Blackwell site would enhance public use of the site and allow development of a diverse plant and animal ecology, both of which are consistent with EPA objectives for Superfund sites. Although EPA promotes redevelopment and reuse of sites when appropriate, its priority is to maintain the integrity of the selected remedy, which at the Blackwell site involves maintaining the integrity of the clay cap. The text should be modified to reflect this priority.*

**Response:**

The Comment is noted and Section 2.0, Paragraph 4 has been modified to state that maintaining the integrity of the clay cap is a priority.

3. *Section 3.0, Page 6, Paragraph 2. According to the paragraph, the literature review indicates that the integrity of the landfill cap "will not be compromised" if tree growth is properly implemented and managed. However, supporting statements made elsewhere in the draft study regarding root penetration are generally less conclusive. For example, Section 3.1 states that root penetration of a landfill cap is "unlikely" and refers to studies showing that about 90 percent of all tree roots and "virtually" all larger roots are found in the upper 2 to 3 feet of soil. Additional justification for stating that cap integrity will not be compromised should be provided, or specific parameters for implementation, management, and monitoring of proper tree growth should be provided.*

**Response:**

The Comment is noted and we agree that some supporting statements regarding root penetration are generally less conclusive. However, because the information was taken from referenced sources, it would be inappropriate to change the text to make the statements more conclusive than the author(s) intended. Therefore, additional text has been added to Section 7.3 of the Draft Final Arboreal Study Report regarding specific parameters for proper implementation, management, and monitoring of tree growth to maintain clay cap integrity.

Just Make  
M.W.'s statement  
Less Conclusive?

4. *Section 3.1.1, Page 7, Paragraph 3 and Section 3.1.2, Page 8, Paragraph 2. These sections incorrectly refer to Sections 3.4 and 4.1 as Sections 2.4 and 3.1, respectively. These errors should be corrected.*

**Response:**

The Comment is noted and Section 3.1.1 and Section 3.1.2 have been modified in the Draft Final Arboreal Study Report.

5. *Section 3.2, Page 9, Paragraph 1. This paragraph states that because tree roots create only half as much tension as is needed to cause cracking of clayey alluvial soils, tree roots are unlikely to cause cap desiccation. If available, additional information should be provided regarding potential changes in such tension requirements based on the moisture content of the soil or the density of the trees.*

**Response:**

Additional text regarding the interaction of clay and tree roots has been added to Section 3.2 of the Draft Final Arboreal Study Report.

6. *Section 3.4, Page 11, Paragraph 3. Case Study 3 states that a complex set of factors help direct root spread, density, orientation, and depth. Additional, quantitative details regarding these factors, particularly as they apply to the Blackwell site, should be provided.*

**Response:**

Case Study 3 has been revised to provide more information on the factors that direct root spread, density, orientation, and depth.

In addition, Sections 5.1 and 5.2 of the Draft Final Arboreal Study Report provide qualitative assessments of soil conditions, including aeration, soil fertility, soil moisture content, temperature, and the effects of leachate and landfill gas. Quantitative factors, including, but not limited to, root zone depth, soil nutrients, and differences in slope and sun exposure, will be evaluated, as necessary, by an ecologist as part of the planting strategy prior to woody vegetation implementation and throughout long term monitoring. Information regarding this quantitative assessment will be discussed in greater detail in the future "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill."

7. *Section 4.1, Page 12, Paragraph 2. This paragraph states that the bulk density values at the Blackwell site are consistent with those at which tree root growth would be reduced or severely restricted; therefore, tree roots "are not expected to" penetrate the clay cap at the Blackwell site. This statement and its associated justification are not conclusive enough to demonstrate adequate protection of cap integrity, particularly considering that the low range of bulk density at the site is below the 109.0 pounds per cubic foot at which root growth is apparently restricted. The text should be revised to provide additional justification for the statement made, specifics on areas of the site where the clay cap does not meet the bulk density threshold, or procedures to ensure that root penetration of the cap will be monitored or prevented.*

**Response:**

The Comment is noted and a new Figure 5 has been added to the Draft Final Arboreal Study Report. This figure has been prepared to illustrate the bulk density values on portions of Blackwell Landfill obtained from soil compaction testing during cap repair activities.

Section 7.3.4 of this report has also been modified to indicate that in the future should clay cap integrity be questioned or should multiple species of trees die, the tree roots will be examined and bulk density testing may be performed. Soil compaction testing during long term monitoring will be discussed in greater detail in "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill."

8. *Section 4.3, Page 13, Paragraph 3. This paragraph summarizes the tree species noted on the landfill. Additional details regarding the height, age, and diameter at*

I don't get  
Would the B.D.  
have killed the trees  
or is it just an opportunity  
to stress roots?

*breast height for tree species at the different areas of the landfill should be provided to support evaluation of the representativeness of the trees selected for the field study.*

**Response:**

The Comment is noted and a description of current vegetative conditions on the Blackwell Landfill has been added in new Section 1.2 of the Draft Final Arboreal Study Report. As well, additional text has been added to Section 4.4 to demonstrate that the trees selected for the field study are representative of the existing trees on the landfill. This additional information was obtained during supplemental field investigation conducted by representatives of Montgomery Watson and Conservation Design Forum on September 23, 1999. U.S. EPA approved the scope of this supplemental field investigation in a September 14, 1999 letter.

- 9. Section 4.3, Page 13, Paragraph 4. This paragraph states that "a couple of areas" were observed where there was no vegetation growth beneath buckthorns. This statement is vague, and additional details regarding the locations and sizes of these areas should be provided.**

**Response:**

Only a limited amount of additional information on vegetation growth beneath buckthorns is currently available. The additional information is provided in Section 4.3. However, it should also be noted that generation of more information regarding the exact location and sizes of existing vegetation growth beneath buckthorns is moot considering that one of the overlying conclusions of the Arboreal Study is that most existing trees and all buckthorns must be removed from the landfill.

- 10. Section 4.4, Page 15, Paragraphs 4 and 5. These paragraphs discuss the results of root penetration for the silver maple but do not specify whether a tap root was present. The presence of a tap root as well as evidence of root penetration and desiccation of the clay layer should be consistently discussed for all trees evaluated.**

**Response:**

Section 4.4 and Table 1 of the Draft Final Arboreal Study Report were modified to specify the whether a taproot was present and whether desiccation of the clay was visible during the field investigation.

- 11. Section 4.5, Page 16, Paragraph 2. This paragraph states that tree roots evaluated during the field study would continue to grow vertically only if no underlying barrier was present and cites only one "minor" instance where tree roots penetrated the compacted clay layer. However, this "minor" instance may be an indication that additional factors, such as the size or age of the trees, the density of the trees, or inconsistencies in the cap density, would affect root penetration at the site. These factors should be considered and discussed accordingly.**

**Response:**

The Comment is noted and the text in Section 4.5 has been modified to state that the tree root in question was identified as a feeder root that penetrated 0.1 feet into the clay cap, and not as a taproot. The exact reason for the observed instance of root penetration is not known, (i.e., the root may have grown into a depression at the top of the clay layer made during original placement or compaction activities). However, as stated previously, a long term monitoring program is intended after woody vegetation implementation.

- 12. Section 5.3.2, Page 19, Paragraph 1. This paragraph states that the slope of the land and weather exposure will affect tree growth on the landfill. Details regarding appropriate slopes for successful tree growth should be provided. In addition, the effects of slope and weather exposure on windthrow potential should be discussed.***

**Response:**

Based on the information provided in Section 3.3, many factors influence tree growth and the potential for windthrow. These factors include “the windiness of the climate region, elevation, topography, soil conditions, rooting depth, the tree’s physical crown and stem condition, the tree’s position in the canopy, the canopy’s density, the surface and subsurface soil conditions, past disturbances, and the wind direction, speed, and duration.” However, the Comment is noted and we have modified Section 7.3.1 of the Arboreal Study Report to indicate that the effects of slopes and weather exposure are to be considered during the development of the future “Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill.”

- 13. Section 7.3, Page 27, Paragraph 2. The removal of unsuitable vegetation discussed in this paragraph should be an ongoing process throughout the restoration effort and should be described as such. In addition, details regarding the frequency of removal and the species targeted for removal should be provided.***

**Response:**

The Comment is noted, and we agree that the removal of unsuitable vegetation should be an ongoing process throughout the restoration effort. We have reiterated this in Sections 7.3.3 and 7.3.4. As well, additional information regarding inappropriate species and frequency of removal will be presented in “Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill.”

**14. Section 7.3, Page 27, Paragraph 8. This paragraph states that planting of trees in a small area may provide just as much "woodland effect" as widespread tree planting. The concept of a "woodland effect" should be explained, and specific definitions of "small area" and "widespread" should be provided.**

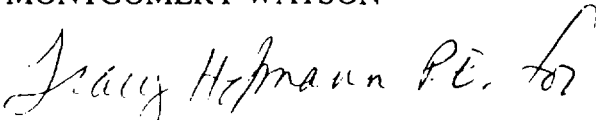
**Response:**

As part of "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill," an ecologist will define the appropriate planting spacing based on the selected tree species. Therefore, the reference to "woodland effect" as compared to widespread tree planting found in Section 7.3, Page 27, Paragraph 8 has been deleted from the text of the Draft Final Arboreal Study Report.

We trust that the above responses to the Agency's comments on the Draft Arboreal Study are acceptable. Please don't hesitate to call me at (630) 836-8900 if you have additional questions or comments.

Sincerely,

MONTGOMERY WATSON



Walter G. Buettner, P.E.  
Supervising Engineer

Attachment 1: Redline/Strikeout version of text  
Attachment 2: Revised Draft Final Arboreal Study Report

cc: Rick Lanham – Illinois Environmental Protection Agency (3 copies)  
Pranika Uppal – Tetra Tech EM, Inc.  
Jerry Hartwig – Forest Preserve District of DuPage County  
Cynthia King, Assistant Regional Counsel – U.S. EPA (without attachments)  
David Barritt – Chapman and Cutler (without attachments)

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**Volume I of II**

**FINAL  
ARBOREAL STUDY REPORT**

**BLACKWELL FOREST PRESERVE LANDFILL SITE  
DUPAGE COUNTY, ILLINOIS**

**Montgomery Watson File No.: 1252008**

**Prepared For:**

**Forest Preserve District of  
DuPage County, Illinois**

**Prepared By:**

**Montgomery Watson  
27755 Diehl Road, Suite 300  
Warrenville, Illinois 60555**

**July 2000**

**FINAL  
ARBOREAL STUDY REPORT**

**BLACKWELL FOREST PRESERVE LANDFILL SITE  
DUPAGE COUNTY, ILLINOIS**

**Montgomery Watson File No.: 1252008**

**Prepared For:**

**Forest Preserve District of  
DuPage County, Illinois**

**Prepared by:** Jennifer M. Smith  
Jennifer M. Smith

7/19/00  
Date

**Approved by:** Walter G. Buettner  
Walter G. Buettner, P.E.

7/19/2000  
Date

## **Executive Summary**

This Arboreal Study Report has been prepared by Montgomery Watson on behalf of the Forest Preserve District of DuPage County, Illinois, and presents a conceptual evaluation of tree growth on the integrity of the existing landfill cap at the Blackwell Landfill in DuPage County, Illinois. The report presents a discussion of the general misconception that tree growth will compromise the integrity of a landfill cap, and refutes this misconception by providing information from a literature review and a root penetration study of existing trees on the Blackwell Landfill. This information indicates that tree roots will adapt to site-specific conditions, will spread laterally when encountering an underlying compacted clay layer, and will not penetrate the compacted layer. The study also suggests that a minimum of two feet of vegetative soil over a compacted clay cap is sufficient to support tree growth on a landfill.

The Arboreal Study Report provides potential restoration strategies for the expansion of woody vegetation on the Blackwell Landfill and provides for the preparation of a follow-up report entitled "Comprehensive Restoration Strategy for the Revegetation of the Blackwell Landfill". This follow-up report will provide site-specific details of the trees and grasses to be planted on the Blackwell Landfill, including specific species, planting locations and maintenance.

However, while the literature review and the root penetration study indicate that tree roots on a landfill will not compromise the integrity of an underlying clay cap, the available case histories are limited in number and do not cover all possible scenarios that could be encountered on a landfill. Therefore, as part of the follow-up report, a comprehensive monitoring program will be developed to monitor vegetal growth and to verify that the future integrity of the clay cap over the Blackwell Landfill will not be compromised. Should information from the monitoring program suggest that woody vegetation could affect the integrity of the clay cap over the Blackwell Landfill, the follow-up report will provide for the removal of problem vegetation and a revision of the planting strategy.

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## **APPENDICES**

- Appendix A Woody Species Report for the Blackwell Forest Preserve Landfill Site  
(Conservation Design Forum)
- Appendix B Thickness of Soil Cover (Detailed)
- Appendix C Deed Restrictions

### **Volume II of II:**

- Appendix D Literature Search

## **1.0 INTRODUCTION**

This Arboreal Study Report has been prepared by Montgomery Watson on behalf of the Forest Preserve District (FPD) of DuPage County, Illinois, and presents an evaluation of tree growth on the integrity of the existing landfill cap at the Blackwell Landfill in DuPage County, Illinois (Site). This report also presents woody vegetation cover options that identify grass and woody vegetation, endemic to DuPage County, which can be safely planted on the landfill without damaging the underlying landfill cap.

The Arboreal Study has been conducted to meet the requirements set forth in the March 7, 1996 U.S. EPA Administrative Order by Consent (AOC) and Statement of Work (SOW), Docket No. V-W-'96-C-341. The AOC and SOW state that root penetration from trees shall not allow percolation of rainwater through the refuse within the landfill. The AOC and SOW also state that the FPD shall develop a rationale for acceptable vegetative cover thickness in combination with specific tree types, and shall develop a tree management program that will not threaten the integrity of the landfill cover.

The purpose of this Arboreal Study Report is to present an evaluation of tree growth on landfills, and to demonstrate that if properly implemented, trees will not harm the integrity of the existing landfill cap at Blackwell Landfill. The evaluation was conducted through a literature review<sup>1</sup>, a multiphase root penetration study, and a review of current growing conditions on the Landfill. This report also provides woody vegetation cover options for the Landfill and protocols for woody vegetation expansion. However, because an end use has not yet been chosen for Blackwell Landfill, specific details, such as the type and number of species to be planted and specific forest and meadow/prairie community types, have not been selected. These details will be developed in a follow-up report entitled "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" that will be submitted prior to any revegetation efforts. The expected contents of this future report are described in a latter portion of this report.

### **1.1 BACKGROUND**

The Blackwell Landfill is located within the Blackwell Forest Preserve approximately six miles southwest of downtown Wheaton, Illinois in Section 26, Township 39 North, Range 9 East, DuPage County, Illinois (Figure 1). The Blackwell Forest Preserve encompasses 1,200 acres of woodlands, grasslands, wetlands and lakes, with the landfill covering approximately 40 acres in the central part of the preserve (Figure 2).

#### **1.1.1 Landfill Construction**

The Blackwell Landfill is located adjacent to an abandoned gravel pit that was purchased by the FPD in 1960. The land was purchased with the intent to create a large hill that could be used by the public for recreational purposes. The FPD began construction of the landfill in 1965, and accepted the final load of refuse in 1973. By the time final contouring and landscaping was

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<sup>1</sup> Copies of most referenced documents are provided in Appendix D

completed in 1975, forty to sixty feet of clay were placed on top of refuse on the southwest side of the landfill to create Mount Hoy. Mount Hoy was finished at an elevation of 839 feet above mean sea level (MSL), approximately 150 feet above the surrounding natural topography. Other areas of the landfill were covered with 2 to 15 feet of predominantly clay cover. In some areas, a vegetative cover of varying sand, gravel and clay composition was placed. A final layer of clayey topsoil (minimum of 4 to 6 inches thick) was installed and vegetated. The final topography of the Site as of 1992 is shown in Figure 3.

The Blackwell Landfill contains approximately 1.5 million cubic yards of refuse classified as general household refuse and light industrial waste. The construction of the hill also includes an equal volume of natural soil fill.

### **1.1.2 Post-Construction History**

In March 1986, the United States Environmental Protection Agency (U.S. EPA) evaluated the Site using the Hazard Ranking System (HRS). A composite score of 35.57 (above the 28.5 threshold for NPL listing) was assigned, with the following scores assigned to each potential route: Surface Water 0.0; Air 0.0; and Groundwater 61.54. The Site was proposed for inclusion on the National Priorities List (NPL) in the Federal Register, Volume 53, Number 122, dated June 24, 1988. The Site received final listing on the NPL in the Federal Register, Volume 55, Number 35, dated February 21, 1990. Subsequent to the final listing on the NPL, a Remedial Investigation/Feasibility Study (RI/FS) was performed at the landfill.

The AOC set forth the required response actions at the Site, which included:

- Delineation of the limits of waste at the landfill edges;
- Cap characterization to delineate areas which did not have two feet of low permeability soil over refuse;
- Repair of those portions of the landfill cover that had less than two feet of low permeability soil over refuse;
- Regrading to promote surface water drainage off the landfill;
- Installation of a leachate collection system (LCS);
- Installation of a passive landfill gas (LFG) venting system;
- Treatment of landfill leachate ; and
- Monitoring of groundwater and system performance.

The required response actions have been completed, or are part of ongoing operation and maintenance.

### 1.1.3 Scope of Study

The required scope of the Arboreal Study was outlined in the U.S. EPA approved Remedial Design Work Plan (Montgomery Watson, April 1996). This Work Plan required: 1) a literature review on the influence that trees and other woody vegetation have on the landfill environment; 2) a field investigation to determine the distribution and depth of the root systems of existing trees on the landfill; and, 3) development of a tree and woody vegetation management plan.

The Arboreal Study was conducted in general accordance with the Work Plan. However, slight modifications to the field investigation were made due to field conditions. Details of these modifications are provided below:

- The Work Plan was based upon the premise that some areas of the landfill may not have a clay cap over refuse. Therefore, the Work Plan provided for three locations on the landfill where existing tree root systems would be evaluated. These locations were to include: a typical depth of vegetative soil cover over a clay capped area, a shallow depth (1 to 2 meters) of vegetative soil cover over refuse, and a deeper depth (2 or more meters) of vegetative soil cover over refuse. However, subsequent investigations indicated that only four areas of the landfill did not have an adequate clay cap over refuse (Montgomery Watson, January 1997), and these four areas were subsequently repaired in 1997 and 1998 by construction of a minimum 2 foot thick compacted clay cap (Montgomery Watson, 1999).

At the time of the arboreal field investigation (December 1998), all areas of the Blackwell Landfill had a clay cap over refuse. Therefore, the field investigation was only able to evaluate existing tree root systems in areas that had vegetative soil cover over a clay cap.

- The Work Plan provided for collection and analysis of soil samples to determine if biologically significant chemical and physical differences in the soil profile had influenced root distribution and rooting depth. However, a site reconnaissance performed in September 1999 indicated that the existing chemical profile in the cover soils was already permitting healthy tree growth, and that collection of chemical data would not provide additional information. As well, considerable information on physical soil information was collected during a predesign investigation (Montgomery Watson, 1997) completed after the Work Plan and prior to the Arboreal Study, and this information was used in lieu of collecting new physical soil data. However, soil chemical data may be collected as part of the future "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" report to confirm that conditions are appropriate for tree growth.
- The Work Plan required that the "root systems of two or more specimens of the same species be excavated to determine the root distribution within the soil profile and the overall depth of the root system." However, as described in Section 4.4 of this report, two of the species studied, the eastern red cedar and the slippery elm, had only one specimen growing within the study area. Therefore, replicate specimens could not be studied.

- The Work Plan required that the Arboreal Study would “involve the development of a tree and woody vegetation management plan for the Blackwell Landfill.” As stated in Section 1, the end use for Blackwell Landfill has not yet been developed. Therefore specific details on the types of woody vegetation to be established have not been determined. Greater detail will be presented in the future report entitled “Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill.”

## 1.2 CURRENT VEGETATIVE CONDITIONS

The current vegetative conditions on the Blackwell Landfill were assessed by Conservation Design Forum (CDF) during a September 23, 1999 field reconnaissance. The purpose of the field reconnaissance was to:

- Generally identify the current tree species over the entire landfill, and provide an estimate of their population;
- Generally describe the health of the different tree species, based upon visual observations only; and
- Note the approximate location and size (i.e., tree height and diameter) of what visually appears to be the largest tree, per species, on the landfill.

CDF determined that most of the trees and shrubs volunteered from seed and vegetative propagation. Only a few pine trees were planted after the landfill was closed. The average age of the woody growth is approximately 10 to 15 years old, and none represents remnant vegetation. CDF also identified fourteen areas (i.e., units) where trees were currently growing on the landfill (Figure 4). The woody vegetation present in each unit is described in detail in Appendix A.

CDF identified a total of 27 species of woody plants (trees and shrubs) on the landfill. Fifteen species (56%) are native to this region, with twelve species (44%) considered non-native. Approximately 250 individual woody plants were noted growing on the landfill with diameters at breast height (DBH) greater than two inches. The DBH is defined as the tree diameter at 4.5 feet above ground surface. The most common woody plants, and their approximate population on the Site, are listed below:

Tree Name	Present Number Of Trees*	Tallest Tree Dbh/height
Green Ash ( <i>Fraxinus pennsylvanica subintegerrima</i> )	92	12"/25'
White Pine ( <i>Pinus strobus</i> )	39	12"/25'
Lombardy Poplar ( <i>Populus nigra italica</i> )	35	8"/25'
Honey Locust ( <i>Gleditsia triacanthos</i> )	22	8"/25'
Box Elder ( <i>Acer negundo</i> )	17	8"/25'
Red Cedar ( <i>Juniperus virginiana crebra</i> )	12	3"/10'
Silver Maple ( <i>Acer saccharinum</i> )	12	6"/20'
White Ash ( <i>Fraxinus americana</i> )	10	4"/20'
Black Locust ( <i>Robinia pseudoacacia</i> )	5	8"/25'
Eastern Cottonwood ( <i>Populus deltoides</i> )	3	14"/25'
Scotch Pine ( <i>Pinus sylvestris</i> )	2	5"/12'
Red Oak ( <i>Quercus rubra</i> )	1	4"/20'
Common Buckthorn ( <i>Rhamnus cathartica</i> )	Saplings	-
Scarlet Hawthorn ( <i>Crataegus coccinea</i> )	Grove	-
Smooth Sumac ( <i>Rhus glabra</i> )	Thicket	-
Staghorn Sumac ( <i>Rhus typhina</i> )	Thicket	-

\* greater than two inch DBH

Most of the Lombardy poplars (the third most common tree on the Landfill) were in poor condition, or were dead. While lombardy poplars can grow 70- to 90-feet tall in 20 to 30 years, they seldom attain this growth due to a canker disease (*Dothichiza populnea*) that develops in the upper branches and trunk. Currently, there is no cure for this particular canker disease.

A total of 57 species of herbaceous plants were recorded on the landfill. Of these, 22 species (39%) are native and 35 species (61%) are non-native. The most prevalent herbaceous species are non-native grasses, including tall fescue, perennial rye, and Kentucky blue grass.

The plant inventory on the landfill was characterized according to U.S. Fish and Wildlife Service protocols to determine their likelihood of being found in wetland or upland areas. The plants on the Blackwell Landfill achieved an average "mean wetness value" of 2.35, which corresponds to a facultative upland environment (i.e., a preference for non-wetlands). Further information on the "mean wetness value" and U.S. Fish and Wildlife Service protocols is found in Appendix A.

In addition, the plant inventory was characterized according to their floristic quality to establish whether the plants represented species that prefer natural or disturbed habitat. The assessment was based upon the characteristics of Chicago region plants, as discussed in *Plants of the Chicago Region*, 4<sup>th</sup> (Swink and Wilhelm, 1994). The resultant assessment yielded a coefficient of conservatism (C) of 0.8, indicating that the current vegetation on the Blackwell Landfill is a degraded or derelict plant community. Further information on the floristic quality assessment is found in Appendix A.

### **1.3 REPORT PRESENTATION**

The report is presented in the following ten sections:

- This section, Section 1 presents the purpose of the Arboreal Study and describes the current conditions at the Blackwell Landfill;
- Section 2 describes the benefits of woody vegetation on the stability of landfills;
- Section 3 summarizes a literature review of tree growth studies on landfills and presents various case studies;
- Section 4 presents the results of root penetration study conducted on the landfill on tree species common to the DuPage County Area. The purpose of this study was to demonstrate that the root systems of trees and woody shrubs currently growing on the landfill have not penetrated the underlying clay cap;
- Section 5 summarizes factors necessary to establish and sustain a healthy woody plants on landfills;
- Section 6 presents the potential restoration strategies for the Blackwell Landfill;
- Section 7 presents the protocols for woody plant expansion;
- Section 8 presents a discussion of potential uncertainties and problems associated with growing trees on landfills, and how the problems would be mitigated;
- Section 9 presents the conclusions of the Arboreal Study; and
- Section 10 contains a list of references.

## 2.0 BENEFITS OF WOODY VEGETATION

Closed landfills represent significant expanses of land and their conversion into recreational areas such as parks and nature centers, is growing increasingly appealing to communities. However, the overwhelming majority of closed sanitary landfills presently utilize various grass species as a final vegetative cover. For closed landfills that are open to frequent public viewing, such as the Blackwell Landfill, the typical 'green dome' landfill feature presents an undesirable appearance. These grass monostands are not ecologically diverse and are expensive to maintain. Without proper maintenance, weed intrusion may invade and dominate the vegetal cover, and cause further deterioration of the landfill's appearance, as weeds grow unabated. However, the undesirable appearance of landfills may be softened by the placement of well-managed and attractive woodland vegetation.

The charter of the FPD is *"to acquire...and hold lands...for the purpose of protecting and preserving the flora, fauna and scenic beauties...for the purpose of the education, pleasure and recreation of the public."* Restoration of the Blackwell Landfill to native woody vegetation and prairie grasses is within the FPD charter, and will enable the landfill to become aesthetically pleasing and blend in with the surrounding forest preserve. In addition, restoration of the Blackwell Landfill will allow the landfill to act as a wildlife corridor and become haven for endangered and threatened plant species.

In addition to public perception, woody vegetation will provide measurable benefits to the overall stability of the soil cover over the landfill, through:

- Erosion control of the soil cover through physical bonding of soil in the root zone;
- Side slope stability where woody plants prevent mass-movement or sliding of soil through mechanical reinforcement and control of soil moisture;
- Reduced net rainfall on the landfill through interception of rainfall on leaves and branches of trees (Dobson and Moffat, 1963); and
- Reduced infiltration potential by evapotranspiration from trees.

The development of woody vegetation on landfills is already occurring in the state of Illinois with the approval of the Illinois Environmental Protection Agency (IEPA). For example, the FPD's Greene Valley Landfill (Woodridge, Illinois) has recently received approval from IEPA for the revegetation of the final cover to native prairie grasses and tree species. The revegetation program consists of replanting several portions of the landfill with differing forest and community types. These community types, including oak woodland and savanna, are consistent with the surrounding flora of the 1,425 acre Forest Preserve.

The U.S. EPA has supported the redevelopment and reuse of Superfund sites. A number of U.S. EPA documents indicate that the reuse of Superfund sites is a priority, and that reuse can include industrial/commercial, recreational or ecological projects. The U.S. EPA's Superfund Reforms

Annual Report for FY1998 provides examples of recreational and ecological projects that include athletic fields, community parks, and habitat preserves. The FPD's desire to maintain woody vegetation on the Blackwell Landfill will enhance the public's use of the Blackwell Forest Preserve, and will allow the development of a diverse plant and animal ecology within the Preserve. While the U.S. EPA's primary priority at the Blackwell Landfill is to maintain the integrity of the selected remedy for the site, which includes the integrity of the clay cap, the FPD believes that the development of woody vegetation on the Blackwell Landfill will not damage the integrity of the clay cap, and will therefore be consistent with U.S. EPA objectives for Superfund sites.

### 3.0 GENERAL CONCERNS

The establishment of woody plants on capped landfills has been discouraged by regulatory agencies due to several misconceptions. These misconceptions are centered on the belief that the integrity of the landfill cap could be compromised by:

- penetration of tree roots through a landfill cap;
- desiccation from tree roots extracting moisture from the cap; or
- high winds over topping trees thereby exposing and tearing the cap (i.e., windthrow).

However, a literature review<sup>2</sup> of these concerns has indicated that the integrity of the landfill cap will not be compromised if tree growth is properly implemented and managed. Details of these concerns are discussed in the following sections.

#### 3.1 ROOT PENETRATION

The function of a landfill cap is to retard water infiltration thereby minimizing leachate generation. Popular belief is that most trees have a deep-rooted system that can penetrate a clay cap, thus compromising the control of water infiltration into the waste. However, the literature review has indicated that tree root penetration of a landfill cap is unlikely.

The architecture, or shape, of root systems is influenced by tree species. Only a small percent of tree species, such as oak, pine, and fir have a large taproot (i.e., the largest root located immediately beneath the tree trunk). However, even in these species, the taproot diameter typically decreases rapidly as secondary roots branch from it (Dobson and Moffat, 1993). In the majority of species, the dominance of the taproot is lost early in development (Dobson and Moffat, 1993).

In the majority of tree species, the lateral roots assume the greatest functional significance. They provide stability, serve as conducting vessels for the nutrients and water absorbed by the smaller roots, and serve as storage organs for the products of photosynthesis (Dobson and Moffat, 1993). These lateral roots may extend outwards from the trunk a distance of between one and three times the height of the tree.

Wagg (1967) conducted a study to evaluate the influence of soil properties, site modification, and spatial organization of roots during growth of white spruce (*Picea glauca*) in central Alberta, Canada. The trees studied ranged from 31 to 88 years old and 18- to 33-feet high. The roots and their origins were thoroughly classified, as well as the surrounding soil characteristics. Four root forms were identified, as summarized below:

- Elongated Taproot: No change in the root form occurs, all roots grow at similar rates, and secondary roots do not develop.

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<sup>2</sup> Copies of most referenced documents are provided in Appendix D.

- **Restricted Taproot:** Growth restriction occurs due to either soil texture, structure, moisture and frost, or because of rapidly growing lateral roots.
- **Monolayered:** Originate from seedling system in which the taproot is either aborted, contorted and aborted, or degenerated at the rootstock.
- **Multilayered:** Development of secondary roots in response to pronounced site conditions.

Wagg (1967) found that the elongated taproot form occurred in well-drained aeolian sands, and were large and well defined. However, the author noted that spruce exhibiting elongated taproots without secondary roots are uncommon. Instead, the taproot was usually restricted and branched at variable depths. The author stated that the growth of the taproot and other roots may be aborted, restricted or contorted by textural changes between soil horizons or restricted by compaction of the underlying soil. The development of secondary roots may also limit the growth of the taproot and therefore limit its overall importance.

Rooting depth studies, conducted in soils without a near subsurface confining layer such as clay or other low permeable material, indicate that for many species of trees, approximately 90% of all tree roots, and virtually all the larger roots, are found in the upper 2 to 3 feet of soil (Dobson and Moffat, 1993). In addition, the number, length, or surface areas of fine and very fine roots diminish rapidly from the surface with depth (Stone and Kalisz, 1991).

Other rooting depth studies indicate that soil aeration and compaction control root depth. These factors are discussed in greater detail in the following sections.

### **3.1.1 Aeration**

The main factor controlling root growth is aeration. Roots require sufficient oxygen for respiration, although the minimum oxygen concentration required for root growth has not been clearly defined (Dobson and Moffat, 1993). Taylor (1971) reported that a reduced oxygen supply almost instantaneously halted root growth, while Dobson and Moffat (1993), reported that in a study published in 1991 by Kozlowski, root growth is greatly restricted when soil oxygen content drops below 10%, and ceases when soil oxygen drops to approximately 3% - 5%.

Dobson and Moffat (1993) reported that in a study published by Yelinosky in 1964 that oxygen concentrations decrease and carbon dioxide concentrations increase with soil depth. Several studies (Flower *et al*, 1978, Gilman *et al*, 1981b, Leone *et al*, 1979), concluded that high concentrations of carbon dioxide may impede or halt the growth of root systems. As well, Leone *et al* (1979) concluded that root damage from carbon dioxide is different from the root damage from a lack of oxygen. However, the mechanism by which carbon dioxide damages plant roots is not known.

A case study of tree growth on a landfill with high carbon dioxide and methane concentrations in the soil is presented as Case Study No. 1 in Section 3.4 of this report.

### 3.1.2 Soil Compaction Within the Root Zone

Soil compaction plays a very important role in aeration and root growth, as well as the stability of a growing tree. Soil compaction controls the availability or exposure of oxygen to the root surface, and can physically impede root growth.

In order to grow, tree roots must physically push aside rocks and soil, and must deform sufficiently to penetrate through an available void (Taylor and Gardner, 1960). The ability for a root to penetrate the soil is a function of the soil strength and soil porosity, including the size, continuity, and tortuosity of the voids within the soil (Taylor and Gardner, 1960 and 1963). In addition, the available room for root growth is restricted by the amount of soil pore spaces that are large enough to sustain root growth (Taylor and Gardner, 1960). Studies by Robinson and Handel (1995) indicate that typical extending root tips have a diameter of 0.1 to 3.0 mm while typical soil pore diameters range from 0.002 to 0.2 mm. Pure clay has even lower pore diameters. In addition, studies by Atwell (1993) indicated that in general, roots that are too thick to find a tortuous path between packed soil particles are likely to find an easier passage through the soil by expanding radially and filling the soil axially. As well, root tissues appear unable to thicken in response to mechanical impedance once primary root growth has ceased.

Several studies have also shown that a high degree of soil compaction reduces root growth because tree roots do not maintain growth if they cannot exert enough root growth pressure to push through the soil (Gilman and Leone, 1981, Robinson and Handel, 1995, Dobson and Moffat, 1993). Root growth pressure is defined as the stress acting normally to the root surface which a root must exert to deform the soil around it (Dexter, 1987). It is a function of oxygen concentration, soil temperature, soil moisture, soil compaction, and the degree of root anchorage in the soil.

Taylor and Ratliff (1969b) conducted a study to determine the effects of soil water content and soil strength on the root length of cotton and peanut plants. In short term experiments, their results illustrated that the roots of both plants grew faster at lower soil compaction values. High compaction decreased the root length, although it did not affect the root volume. Additionally, root elongation rates as a function of soil strength were not affected by soil water content. In a comparable study conducted with cotton seedlings, Taylor and Gardner (1963) similarly concluded that an increase in soil strength not only reduced the percentage of roots penetrating the soil, but also decreased root growth rate.

Heilman (1981) conducted a study to identify the upper limit of soil compaction that would cease root penetration, and to determine the relationship between root growth and soil density. His study of Douglas-fir (*Pseudotsuga menziesii*) seedlings concluded that relatively minor increases in soil density may have significant adverse effects on tree seedlings. Total penetration and vertical penetration of primary roots decreased linearly in soil with bulk densities in the range of 85.3 lb/ft<sup>3</sup> through 110.3 lb/ft<sup>3</sup>, while growth was restricted with soil bulk densities ranging from 109.0 lb/ft<sup>3</sup> through 114.0 lb/ft<sup>3</sup>. Observations of root growth patterns in the compacted soil environments showed that the roots grew laterally along the interface of the compacted soil, which may indicate an adaptation of the root architecture to compensate for restricted vertical rooting. (NOTE: A comparison of bulk densities measured within the Blackwell Landfill clay cap is provided in Section 4.2.)

As reported in Dobson and Moffat (1993), Bowen published a study in 1981 that determined that heavier soils restricted root penetration at lower bulk densities than lighter soils, and that dense soils, such as compacted clay, provide barriers due to limited available pore space for root growth.

The soil fabric, or environment, is also a major contributor to the root's physical behavior, and controls water, heat, aeration, and strength relationships that are important for determining overall root growth (Taylor, 1971). Based on a data summarization of 49 families, 96 genera, and 211 species, Stone and Kalisz (1991) reported that root branching is constrained by the patterns of joints, bedding planes, or other voids in the soil environment. Moreover, unfissured dense layers, poorly aerated horizons or water tables are barriers to deep root penetration (Stone and Kalisz, 1991). This is supported by the inability of roots to penetrate fragipans, which are defined as a natural subsurface horizons having a higher bulk density than the soil above (Fernandez *et al.*, 1995, Singh and Sainju, 1998, and Grecu *et al.*, 1988). In addition, if no cracks in a vertical physical barrier are encountered, the roots are diverted laterally and may continue to grown horizontally along the surface until growth conditions change (Taylor, 1971). Under similar conditions, misshapen, but physiologically active, roots may grow in response to soils high in clay content (Taylor, 1971).

### 3.2 CAP DESICCATION

Damage to the integrity of a landfill cap due to vegetation-induced cap desiccation is often raised as a concern. The basis for this concern is that if tree roots were growing in or on top of a clay cap, water uptake from the roots may cause the clay cap to desiccate and crack. This in turn could lead to increased infiltration of precipitation into the landfill, and the release of landfill gas from the landfill. However, tree roots are not considered a contributor to potential cap desiccation because of the roots inability to penetrate a compacted clay (as described above), and because a physical limitations on the amount of water that tree root systems can remove.

Cap desiccation due to water uptake by tree roots implies that the roots could physically remove enough water to cause cracking of the clay cap. This would be accomplished through direct absorption of water by roots in contact with the cap. However, studies on moisture uptake by tree roots indicate that tree roots can only exert approximately 1.0 MPa to 1.5 MPa of moisture tension in soil (Reeve and Hall, 1978, and Bronswijk, 1991). Bronswijk concluded that desiccation cracking in clayey alluvial subsoils was not observed until moisture tensions exceeded approximately 4.0 MPa. Moreover, as reported in Dobson and Moffat (1993), Gregory published a study in 1988 that showed water uptake by plants is severely restricted at tensions as low as 1.0 MPa. Therefore, since tree roots create only half as much tension needed to cause cracking, tree roots are unlikely to cause cap desiccation.

### 3.3 WINDTHROW

Potential windthrow damage to landfill caps is caused by the overtopping and uprooting of trees, which in turn can expose or otherwise tear the underlying cap. As reported in Dobson and Moffat (1993), a study by Schaetzl *et al* in 1989 defined windthrow as, "the technical term for trees being blown over by strong winds, and it can involve snapping of the trunk or uprooting."

Landenberger (1997) has defined a number of conditions that determine the potential for windthrow. These conditions include the windiness of the climate region, elevation, topography, soil conditions, rooting depth, the tree's physical crown and stem condition, the tree's position in the canopy, the canopy's density, the surface and subsurface soil conditions, past disturbances, and the wind direction, speed, and duration.

Elevation effects on windthrow are coupled with mean wind speed and gale frequency. At higher elevations, winds are typically stronger than in low-lying areas. Therefore, trees at higher elevations are more susceptible to windthrow than those at lower elevations. Topography also is an important factor in determining windthrow potential. The relative exposure of a tree or group of trees is a function of the degree of provided shelter. At high elevations, trees are less likely to be toppled if surrounding high areas shelter them. Similarly, surrounding high points protect lowland trees.

Another critical factor in determining windthrow involves soil condition. Trees growing on wet soils are more likely to be uprooted than those on drained sites. This is due to high moisture decreasing soil cohesion and soil strength (Dobson and Moffat, 1993). Conversely, windthrow potential decreases when tree roots are anchored in frozen soil (Peltola, 1995). Moreover, stony soil tends to provide less soil cohesion than stone-free soils (Dobson and Moffat, 1993).

Windthrow hazards may be reduced if trees are planted in stands rather than singular individuals. Common silvicultural, or forestry, practices suggest that trees in unthinned stands will be more stable than trees planted in thinned stands (Dobson and Moffat, 1993). This was confirmed by observations of trees toppled by Hurricane Donna (Trousdel *et al*, 1965). The high winds did heavier damage in thinned stands of loblolly pines than in unthinned stands. In addition, Peltola (1995) observed that trees growing along a stand edge are subjected to greater wind loading than trees within a given stand.

Windthrow hazards may also be reduced if smaller trees are utilized. A smaller tree will have less total area exposed to the wind than a larger tree because the total exposed crown area will be reduced, and if toppling occurs, a smaller tree will have a proportionally smaller amount of disturbed soil (Dobson and Moffat, 1993). This was confirmed by a modeling experiment conducted by Peltola (1995) where the windspeed required to topple a tree decreased as the height to diameter ratio, the crown to stem weight, or the tree size increased.

### 3.4 CASE STUDIES

The following case studies provide a discussion of the adaptation of root architecture and growth patterns found at three sanitary landfills in the eastern United States. These studies indicate that the tree root system has the ability to adapt to limited soil cover and an underlying compacted clay barrier.

#### Case Study 1: Edgeboro Landfill, East Brunswick, NJ

Gilman *et al* (1981a) conducted a study of the Edgeboro Landfill, completed in 1966. Between 6 and 9 inches of soil had been placed over the municipal refuse as a final cover. The authors added 1 foot of sandy subsoil and approximately 6 to 9 inches of additional topsoil to increase the total depth of vegetative cover to approximately 2 feet. This amended landfill cap did not act as a barrier to landfill gas, and carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) diffused through the cover. A control plot was established one-quarter mile from the landfill plot in undisturbed woodland. In order to replicate landfill soil conditions, the control plot was amended with additional sandy soil and topsoil. Nineteen woody species, including pin oak (*Quercus palustris*), American basswood (*Tilia americana*), green ash (*Fraxinus pennsylvanica*) and honey locust (*Gleditsia triacanthus*), were planted on both experimental plots and were evaluated for their ability to tolerate the landfill's soil conditions.

The study determined that there was an inverse relationship between landfill gas concentrations and total root growth. In landfill areas with high landfill gas concentration, 35% of tree roots were located in the top 6 inches of soil. In landfill areas with low gas concentrations, only 3.8% of roots were located in the top 6 inches. In many instances, tree roots were able to adapt their root architectures to avoid high gas areas. For example, a honey locust planted on the landfill grew an approximately twelve foot long lateral root that originated 2-inches below ground surface and remained at this depth throughout its entire length.

As well, the tree root systems on the landfill (in areas with both high and low gas concentrations) had significantly shallower root systems than trees growing on the control plot. For example, ash seedlings growing on the control plot exhibited roots that were twice as long and deep as seedlings growing on the landfill. In addition, the control plot seedlings grew almost vertically and did not exhibit the matted, shorter root zone of the landfill seedlings.

However, tree species that naturally produce shallow root systems were able to grow well on the landfill plot. Gilman *et al* (1981a) concluded that oxygen levels in the soil and the availability of the oxygen significantly effected the depth of the roots. The authors suggested that landfill gases be minimized in the root zone to promote healthy vegetation growth.

#### Case Study 2: Brookfield Sanitary Landfill, Staten Island, NY

Robinson and Handel (1995) conducted a study on the Brookfield Sanitary Landfill in the fall of 1992 to determine if woody plants could maintain growth in 1 foot or less vegetative soil cover over a 1.5-foot thick barrier clay. Nineteen species of woody plants were identified on the closed landfill; thirteen species had large individuals growing on the landfill. Volunteer species growing on the landfill ranged from 3 to 19.5-feet tall, with a maximum growth period of seven years.

Test species that are native to Illinois included the grey birch (*Betula populifolia*), sweet gum (*Liquidambar styraciflua*), mulberry (*Morus* sp.), black cherry (*Prunus serotina*), pin oak (*Quercus palustris*), and black locust (*Robinia pseudoacacia*).

The root systems of thirty trees, and the underlying impacts to the clay barrier, were examined during the study. In all thirty specimens, shallow root systems were observed. Although the trees studied had a wide variety of potential root growth forms, all roots were found growing above the clay layer. Taproots of various sizes were found deformed, and growing entirely above and parallel to the clay barrier. As well, the root systems for black cherry and pin oak, which reportedly can produce taproots that extend to depths greater than 3 feet, had no significant penetration into the clay barrier. The maximum root depth was equivalent to the depth of vegetative soil cover overlaying the clay barrier. For trees as tall as 20 feet, the overall root mass spread laterally rather than downward. The tree growth rate was not adversely impacted due to the shallow vegetative soil cover, with many trees being of average height and with sizable lateral root systems.

### Case Study 3: Fresh Kills Sanitary Landfill, Staten Island, NY

Handel *et al* (1997) conducted a study in 1992 and 1993 on a closed portion of the Fresh Kills Sanitary Landfill, one of the largest municipal facilities ever constructed. An 18-inch thick clay cap, followed by 2 feet of vegetative soil, covered municipal waste. Seventeen species of native trees (ranging from 5 to 7.5-feet tall) and shrubs (ranging from 2 to 3.2-feet tall) were planted and studied for root growth dynamics. Approximately 550 individuals were planted at 5-meter intervals in a 15-row grid across the study area. The planted trees that are native to Illinois included red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), eastern red cedar (*Juniperus virginiana*), pitch pine (*Pinus rigida*), eastern white pine (*Pinus strobus*), American sycamore (*Platanus occidentalis*), black cherry (*Prunus serotina*), pin oak (*Quercus palustris*), and chestnut oak (*Quercus prinus*). In addition, the same species were planted on an adjacent earth berm to serve as a control group.

Specimen excavation was performed on both the landfill trees and control group to compare root architecture and growth depth. Observations showed that the rooting depths of the landfill trees were significantly less than the control group planted in identical subsurface soil. Additionally, in over three years of growth, no damage to the clay cap was observed, even as the depth of cover soil above the landfill cap ranged from 12 to 39-inches. It is important to note that many of the trees planted during the study had the capability of extending vertical roots below the depth of the overburden placed over the clay cap (as reported in Stone and Kalisz, 1991). In addition, no significant difference was observed in lateral fine root depth based on slope position or depth to the capping clay.

The authors state that species-specific differences in root morphology may not provide an adequate basis for selecting appropriate tree species to be planted above a clay barrier. Genetics, in combination with environmental factors, including soil mechanical resistance, moisture, aeration, pH, and environmental or abiotic factors, help dictate root spread, density, orientation, and depth. Additionally, the authors state that root growth is plastic and distinctions between root forms blur with respect to engineered soils. After the early stages of seedling development,

tree and shrub roots will respond to the spatial and temporal variability between favorable and unfavorable soil conditions rather than grow blind to present environmental conditions.

### **3.5 SUMMARY**

The case histories and literature review indicate that trees on landfills, regardless of tree species and the thickness of the vegetative soil cover, develop shallow, lateral root systems that do not penetrate an underlying compacted clay cap. The factors limiting root depth are oxygen content, and the compaction of the soil beneath the roots. The case studies suggest that a minimum of one foot to two feet of vegetative soil cover over a clay cap is sufficient to safely sustain trees on a landfill.

## **4.0 ROOT PENETRATION STUDY AT BLACKWELL FOREST PRESERVE**

A root penetration study was conducted at the Blackwell Landfill to demonstrate, in conjunction with the literature research, that the root systems of trees and woody shrubs would not penetrate the clay cap given sufficient soil cover. The root penetration study was conducted in three phases. The first phase of the study was to identify the amount of existing vegetative soil cover present on the landfill (Section 4.1) and the existing characteristics of the clay cap (Section 4.2). The second phase consisted of a site reconnaissance specifically focusing on those areas of the Blackwell Landfill that were considered to have suitable vegetative cover (Section 4.3). The third phase was a field study to determine if tree roots in the areas of suitable vegetative cover compromised clay cap integrity (Section 4.4).

### **4.1 EXISTING VEGETATIVE SOIL COVER**

The distribution and thickness of the vegetative soil cover over the compacted clay cap on the Blackwell Landfill was mapped using soil boring data compiled during the following previous investigations:

- Blackwell Forest Preserve Deep Vents and Exploratory Borings (Testing Service Corporation, 1986);
- Technical Memorandum Predesign Investigation (Montgomery Watson, 1997); and
- Revised Predesign Report (Montgomery Watson, 1997).

The data indicates that the thickness of vegetative soil cover on parts of the Blackwell Landfill vary from less than six inches (i.e., topsoil) to greater than twelve feet. However, there are only four definable areas on the landfill that have vegetative soil cover greater than one foot thick (Figure 5). A map which provides test boring details is provided in Appendix B. On the rest of the landfill, either the vegetative soil cover is less than one foot thick, or the lateral extent of the vegetative soil cover greater than one foot could not be defined.

### **4.2 EXISTING CLAY CAP**

The compaction and permeability of the soil determine the availability of the oxygen to the root surface, and the physical ability of roots to grow. As discussed in Section 3.1.2, tree roots will not penetrate tight, highly compacted soil because of physical impedance and reduced pore volumes that limit oxygen diffusion. Tree roots will not grow if they cannot exert enough pressure to push through the soil. As stated in Section 3.1.2, root studies conducted by Heilman (1981) indicate that total and vertical penetration of primary tree roots (Douglas-fir seedlings) decreased linearly with bulk densities in the range of 85.3 lb/ft<sup>3</sup> through 110.3 lb/ft<sup>3</sup>, while growth was restricted with soil bulk densities ranging from 109.0 lb/ft<sup>3</sup> through 114.0 lb/ft<sup>3</sup>.

The bulk density of the clay cap at the Blackwell Landfill has been tested during the course of the recent remedial actions at the site (Figure 6). A cap delineation study (Montgomery Watson, 1997) indicated that the dry bulk density of the original clay cap, not including areas that were subsequently repaired, varies from 110.4 lb/ft<sup>3</sup> to 131.4 lb/ft<sup>3</sup>, with an average density of 120.8 lb/ft<sup>3</sup>. As well, quality assurance testing conducted during repair of the cap in 1997 and 1998 indicated that the dry bulk density of the repaired cap varied from about 101.1 lb/ft<sup>3</sup> to 119.9 lb/ft<sup>3</sup>, with an average density of 113.1 lb/ft<sup>3</sup> (Montgomery Watson, 1999). These values are consistent with soil environments identified by Heilman (1981) at which tree root growth would be reduced or severely restricted. Therefore, tree roots are not expected to penetrate the clay cap on the Blackwell Landfill.

### 4.3 SITE RECONNAISSANCE

A site reconnaissance was conducted at the Blackwell Landfill to identify the number and types of woody species within the defined areas of vegetative soil cover (Figure 5), and to identify the dominant vegetation over the remainder of the landfill. Montgomery Watson and CDF conducted the reconnaissance on October 28, 1998.

The site reconnaissance indicated that, in general, most plant species on the landfill appeared healthy, with the majority of the landfill covered by various non-native grass species, such as *Bromus inermis* (Hungarian brome) and *Poa pratensis* (Kentucky blue grass). *Coronilla varia* (crown vetch) was also noted on several parts of the landfill. Crown vetch is a shallow-rooted perennial forb that was previously considered choice vegetation for landfills to prevent erosion. However, recent experience shows that crown vetch has shallow and weak roots, and is less able to prevent soil erosion compared to native prairie species.

The site reconnaissance also indicated that native and non-native tree species are currently present on several areas of the landfill, although few trees were noted on the landfill's southern side, possibly due to steeper slopes. Sixteen species of woody plants were observed growing within three of the four areas with 1 foot or greater of vegetative cover soil. The fourth area was void of trees or woody shrubs. A complete list of woody species and the dominant herbaceous species identified in the four defined areas is provided in Appendix A. The tree species growing outside the four areas of vegetative soil cover were not fully cataloged.

The site reconnaissance identified a number of non-native tree species that are considered invasive and competitive with native flora (such as oaks), including *Rhamnus cathartica* (common buckthorn) and *Elaeagnus umbellata* (autumn olive), both located in Areas 1, 2 and 4. These competitive non-native species can be detrimental to a landfill cap. For instance, buckthorns have very dense leaf canopies that shade the ground. Bottom layer plants that require some sunlight, such as the brome grass found at the Blackwell Landfill, are unable to maintain growth beneath the buckthorns and die. With the bottom layer plants gone, the soil becomes highly susceptible to erosion. The field reconnaissance observed a couple of areas where there was no vegetation growth beneath the buckthorns.

As well, the field reconnaissance identified other trees that were overgrown, or were in poor health due to naturally-occurring tree diseases not attributable to the landfill. These species included *Populus nigra italica* (Lombardy poplar) which are cankerous as stated in Section 1.2, and *Populus alba* (white poplar). Other species, such as a grove of *Malus coronaria* (crab apple), appear to have been planted in their present locations along a landfill access road.

The site reconnaissance did not reveal any evidence of windthrow.

#### 4.4 FIELD STUDY

Montgomery Watson and CDF conducted the root penetration study on December 9, 1998. The study was originally intended to focus on trees selected from areas of vegetative soil cover that were greater than 2 feet thick. However, suitable trees for the study (see below) were identified in only one of the four areas. Therefore, the study was expanded to nearby unmapped areas that also had suitable trees.

The root penetration study was conducted on five trees at the locations shown on Figure 5. These five trees were selected based upon:

- Generally being native to DuPage County;
- Having acceptable aesthetic qualities;
- Having a variety of different rooting systems; and
- Appearing healthy.

The specific species chosen for the study were an eastern red cedar (*Juniperus virginiana crebra*), slippery elm (*Omus pumila*), smooth sumac (*Rhus glabra*), silver maple (*Acer saccharinum*), and a honey locust (*Gleditsia triacanthos*).

The root penetration study consisted of excavating the tree, exposing the root system by tipping the tree on the ground, and examining the root systems of each tree. The root configuration, soil types and thickness, approximate height of the tree and the DBH were noted. As noted previously, the DBH is defined as the tree diameter at 4.5 feet above ground surface. Cross-sections summarizing the information obtained are shown in Figures 7 through 11. Select information is also tabulated in Table 1.

##### **Eastern Red Cedar (Area 4, south of Unit 9):**

The Eastern Red Cedar was located in Area 4 on the west-side of the landfill (Figure 5). The area was generally flat, and was mostly covered by brome grass. The red cedar was located approximately 50 feet southeast of leachate extraction well EW08. The cedar is a type of conifer that typically has a shallow root system. This cedar was approximately 10.5 feet tall and 2 inches DBH. The tree appeared to be healthy.

Soil was excavated next to the tree to a depth of 2.8 feet below ground surface (bgs) prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and

Figure 7. The cedar's root system consisted of shallow woody roots that spread out laterally a distance almost equal to the canopy diameter of the tree. A taproot did not exist, and the deepest woody root observed penetrated 1.5 feet bgs, which corresponds to the top of a clayey gravel layer. No root penetration into the compacted clay layer was evident, and there was no evidence of desiccation cracking of the clay below the tree roots.

A total of 20 eastern red cedars are present in three of 14 units on the landfill. The largest individual found on the landfill was 3" DBH and 10 feet tall. The cedar that was excavated during the root penetration field was of comparable height to the largest cedar on the landfill. [Note: The cedar was not documented during the 1999 field reconnaissance because the tree was not replanted following excavation.]

#### **Slippery Elm (Area 4, south of Unit 9):**

The slippery elm was located near the perimeter of Area 4, approximately 75 feet east of leachate extraction well EW08 (Figure 5). The elm stood in a stand of diseased poplar trees, although the elm appeared to be healthy. The elm was approximately 10.5 feet tall and 2.5 inches DBH.

Soil was excavated next to the tree to a depth of 2.4 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 8. The elm exhibited long horizontal roots with a maximum root penetration depth of approximately 1.6 feet bgs, with a nominal penetration by a small "feeder root" of approximately 0.1-foot into the underlying compacted clay layer. A taproot did not exist, and there was no evidence of desiccation cracking of the clay below the tree roots.

The slippery elm was the only individual of its species growing on the landfill, and was the only elm identified in both the 1998 and 1999 field reconnaissance studies.

#### **Smooth Sumac (outside of Area 3, inside Unit 11):**

The smooth sumac was located on the southern slope of the landfill (Figure 5) in an area covered by a combination of brome grass and crown vetch. The sumac was located approximately 250 feet east of vent SV12. The selected sumac was positioned near the center of a colony of sumacs (i.e., sumacs propagate by cloning). The sumac was approximately 10.8 feet tall with a DBH of 2.5 inches.

Soil was excavated next to the tree to a depth of approximately 2.0 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 9. A taproot was not evident, and there was no evidence of desiccation cracking of the clay below the tree roots. The maximum root penetration depth of 1.3 feet bgs, which corresponds to the top of the clay fill layer (i.e., the roots did not penetrate the compacted clay layer).

The average DBH and height of the sumacs in this thicket are 1 inch and 8 feet tall, respectively. The smooth sumac chosen for the root penetration field study was 2.5" DBH and 10.8 feet tall, which makes the excavated sumac larger than average.

#### **Silver Maple (outside of Area 3, outside Unit 11):**

The silver maple was also located on the south side of the landfill to the west (Figure 5), and adjacent to, the sumac colony. The silver maple is not a native species; however, it was one of the tallest trees currently on the landfill. The silver maple was 15 feet tall with a DBH of 4 inches.

Soil was excavated next to the tree to a depth of approximately 4.5 feet. The silver maple was not tipped. Details of the observed root system and soil types are presented in Table 1 and Figure 10. The underlying compacted clay layer was not encountered in the excavation; a deeper excavation was not possible due to the surrounding steep landfill slopes. Roots were observed to be growing to the maximum depth excavated, and a taproot was not identified. Desiccation cracking was not evident at the maximum depth of excavation.

The largest silver maple on Blackwell Landfill was estimated at 6" DBH with a height of 20 feet, which is comparable in size with the excavated silver maple. The silver maple was found in two units of the landfill, with a total count of 42 individuals (including saplings).

#### **Honey Locust (outside of Area 3, outside Unit 11):**

The honey locust is located on the south side of the landfill (Figure 5), in an area mostly covered with grasses and crown vetch. The honey locust was located approximately 100 ft south of landfill gas vent SV12 between two adjacent honey locust trees. The honey locust was approximately 10.5 feet tall with a DBH of 2 inches.

Soil was excavated next to the tree to a depth of approximately 2.8 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 11. A taproot was not present, and all large roots were observed to be growing horizontally. Lateral roots were not observed below 0.9 feet bgs. The tree roots extended to a maximum depth of 2.3 feet bgs, which is within a wet, uncompacted clay layer. No root penetration into the compacted clay layer was evident and there was no evidence of desiccation cracking of the clay below the tree roots.

Sixty-seven honey locust trees were noted in three units during the 1999 field reconnaissance. The largest honey locust is located on a berm in the northern part of the landfill (Unit 2), and measures 8 inches DBH and 25 feet tall. The honey locust chosen for the root penetration study was positioned on the steeper southern slope of the landfill.

## **4.5 SUMMARY**

The environmental conditions on the Blackwell Landfill currently support a diversity of plant life on all sections of the landfill. The majority of the landfill is covered by various non-native grass species, such as *Bromus inermis* (Hungarian brome) and *Poa pratensis* (Kentucky blue grass), with *Coronilla varia* (crown vetch) also noted on several parts of the landfill. Sixteen species of woody plants were noted in the four defined areas of adequate vegetative soil cover on the landfill.

A root penetration study was conducted on five trees located on the landfill. The tree roots were excavated, and the root configuration and soil types and thickness were noted. This study indicates that the tree roots spread laterally when they encountered an underlying soil barrier such as the clay cap, and would only continue to grow vertically if there was no underlying barrier. Desiccation cracking of the clay underneath the tree roots was not evident during the root penetration field study. Except for one minor instance where the total thickness of vegetative soil cover was only 1.5 feet thick, the tree roots did not penetrate the underlying compacted clay cap. Even in this instance, one tree root, identified as a feeder root and not a taproot, only penetrated approximately 0.1 feet into the compacted clay. This penetration of the feeder root is not considered significant.

## **5.0 FACTORS AFFECTING TREE GROWTH ON LANDFILLS**

By its nature, a landfill may not provide the most hospitable environment for long-term, sustainable growth. Therefore, numerous conditions must be considered when establishing a tree management plan for a landfill. This includes soil conditions (e.g. soil aeration, permeability, fertility and moisture), external factors that are somewhat unique to landfills (e.g. landfill gas and leachate production), location on the landfill, and care and maintenance. The following sections provide general information regarding these factors, and how they relate to the Blackwell Landfill.

### **5.1 SOIL CONDITIONS**

#### **5.1.1 Aeration**

Soil aeration is necessary for a tree's survival, and is a governing factor that controls the depth of root growth. Oxygen is required for respiration, and a reduced oxygen supply will almost instantaneously halt root growth. While the minimum concentration of oxygen required for root growth has not been clearly defined, as reported in Dobson and Moffat (1993), studies by Kozlowski reported the when soil oxygen content drops below 10%, root growth is greatly restricted and at approximately 3% - 5%, root growth ceases.

The current oxygen levels in the vegetative soil cover at the Blackwell Landfill are not known. However, even without the benefit of a quantitative study, several qualitative observations can be made at about the oxygen levels at the site. The Blackwell Landfill has well-established vegetation, as described in Section 1.2, as well as several areas with shrubs and trees. The vegetation is healthy and does not appear to be stressed. In addition, the Blackwell Landfill has a minimum two-foot thick clay cap over refuse, which acts as a barrier to oxygen depletion in the root zone by preventing landfill gas migration. Therefore, the oxygen levels in the vegetative soil cover at the Blackwell Landfill are adequate to sustain vegetation.

#### **5.1.2 Soil Fertility**

Tree root growth and development are dependent on the available nutrients in the soil environment. The major nutrients for tree growth include magnesium, phosphorus, potassium, and calcium, while the minor nutrients include nitrogen compounds and the trace elements iron, manganese, zinc, copper, and boron (Flower *et al*, 1978). However, the concentrations of metals in the soil must have a delicate balance in order to foster tree growth, and soils with high concentrations of heavy metals should be avoided (Gilman *et al*, 1985).

Soil fertility does not appear to be a problem at the Blackwell Landfill. The number and variety of species growing on the landfill and their relatively healthy appearance support this conclusion. In addition, based on the root penetration study (Section 4.4), the examined root systems appeared healthy and well branched.

### **5.1.3 Soil Moisture Content**

An excess or deficiency in soil moisture content can greatly affect the ability of a tree to grow. Excess soil moisture, or water logging, can lead to decay or death of the existing root system, while drought conditions can impede root growth or cause root damage.

Soil moisture content does not appear to be a concern at the Blackwell Landfill based on the number and variety of species currently being supported. The landfill's topography is suited to promote runoff. Moreover, during the root penetration study, water logging was not observed, as evidenced by the absence of decaying or dead roots and a stagnant water layer present above the compacted clay cap.

## **5.2 EXTERNAL CONDITIONS**

### **5.2.1 High Temperatures**

Elevated soil temperatures at closed sanitary landfill can damage trees by decreasing soil moisture and providing too warm of a soil environment in the root zone. However, higher soil temperatures may also extend the growing season, and could provide some protection from winter or spring frosts (Ruark *et al* 1982). Although the optimum root zone temperature varies with tree species, the average optimum root zone temperature is between 10 to 30 °C.

Elevated soil temperatures at the Blackwell Landfill do not appear to pose a problem. The landfill has well-established, healthy vegetation. The trees on the Landfill are estimated to be 10 to 15 years old, and they would not have survived if the temperature levels in the soils were too high.

### **5.2.2 Leachate**

Leachate is the term for the resultant liquid that is generated in a landfill as water infiltrates through the waste. Leachate can have a chemical makeup that is toxic and harmful to vegetation, although at some landfills, captured leachate has been irrigated into plots of trees as a means for leachate disposal (Dobson and Moffat, 1993). Damage to vegetation usually occurs only at the landfill surface where a leachate seep is occurring. Typically, leachate seeps occur on the edges of landfill or in low-lying areas where there is little or no cap.

Damage to vegetation from exposure to leachate is not occurring at the Blackwell Landfill, and is not expected to occur in the future. There are no known leachate seeps, and all vegetation appears to be healthy except for known tree diseases (non-landfill related). As well, the leachate at the Blackwell Landfill is controlled through a leachate collection system installed in 1997.

### **5.2.3 Landfill Gas**

Landfill gas is a complex composite of gas generated during the decomposition of biodegradable waste contained within the landfill. Typically, gas production peaks in a number of years following landfill closure, and then declines over time. Methane and carbon dioxide typically comprise the largest volume of the gas. This gas can migrate from the landfill and diffuse through the compacted cap to the root zone. Harmful effects from landfill gas are caused by the

gas displacing oxygen and elevating carbon dioxide levels. Elevated levels of carbon dioxide have been shown to be toxic to tree roots (Dobson and Moffat, 1993).

Methane is a flammable, colorless and odorless gas that is lighter than air. Methane mixed with air can be explosive. The explosive limits of methane, expressed in percent volume, range from 5% to 15%. Typical ranges of methane measured at gas vents at the Blackwell Landfill during routine operation and maintenance activities vary from 0% (no methane) to 65%.

Historically, landfill gas accumulation at the Blackwell Landfill has been controlled by a series of individual passive vents. This system was augmented in 1997 by an engineered gas extraction system. In December 1999, Montgomery Watson submitted a draft work plan to the U.S. EPA requesting approval to undertake significant modifications to the current passive LFG venting system at Blackwell Landfill. This draft work plan proposed that the LFG emission sources be reconfigured through underground piping so that the main LFG vent stack becomes the only LFG emission source on the Blackwell Landfill. This reconfiguration would virtually eliminate methane as an ignition source on the landfill.

There is no evidence of landfill gas causing damage to vegetation at the Blackwell Landfill. All vegetation appears to be healthy except for known tree diseases. In addition, there is historical evidence that suggests that gas production at the landfill has been declining over the past ten years.

## **5.3 LOCATION**

### **5.3.1 Slope And Sun Exposure**

The slope of the land and the weather exposure will effect the success of tree growth on the landfill. Certain trees may not fair well on parts of Mount Hoy that have very steep slopes. The success of any woodland cover will require that slope and weather exposure be evaluated with respect to the species of trees planted and maintenance requirements. As well, if mechanical devices are used to plant trees, the maximum safe slope for the equipment is three horizontal to one vertical.

### **5.3.2 Location of Control Structures**

The Blackwell Landfill's leachate collection system (LCS) currently consists of nine extraction wells and two lift stations that are located at the north and south areas of the landfill. Twelve shallow and sixteen deep gas vents are also located throughout the landfill. Four manholes help direct storm water to the lift stations. An access road to the top of Mount Hoy is present in the southern half of the landfill. Tree restoration in these areas must be designed and implemented as not to interfere with these features because they are imperative to the daily operation and maintenance of the landfill. In addition, intrusive activities near any LCS components will not be allowed as it may cause damage to the buried piping. Trees must not be planted over the LCS conveyance piping.

### 5.3.3 Natural Habitat Area

The Blackwell Landfill is located immediately north of the Blackwell Kame<sup>3</sup> (Figure 2). This eight-acre area is the only kame in DuPage County that still contains a high-quality remnant prairie and woodland. The FPD has been managing the Blackwell Kame over the last 20 years with regular, controlled burns, and in recent years there has been some restoration activity in the ambient woodlands.

The Blackwell Kame is the only known location in the county for rare species such as *Arenaria stricta* (stiff sandwort) and *Carex umbellata* (early oak sedge). Other rare species include *Asclepias viridiflora* (short green milkweed), *Brachyelytrum erectum* (Long-awned wood grass), *Bromus latiglumis* (eared-leaved brome), *Carex meadiei* (Mead's stiff sedge), *Echinacea pallida* (purple coneflower), *Eryngium yuccifolium* (rattlesnake master), *Helianthus occidentalis* (western sunflower), *Hypoxis hirsuta* (yellow star grass), *Lathyrus venosus* (veiny pea), *Liatris cylindracea* (cylindrical blazing star), *Lithospermum latifolium* (broad-leaved pucoon), *Panicum leibergii* (prairie panic grass), *Scutellaria parvula* v. *leonardi* (small skullcap), *Silene virginica* (fire pink), and *Viola pedatifida* (prairie violet). One of the largest known white oaks in DuPage County is situated along the western edge of the kame.

The Blackwell Kame is considered a highly valued nature habitat within DuPage County, and the Blackwell Landfill is located in its buffer zone. Managing the non-native, "undesirable" species on the landfill, such as Eurasian weeds and trees, will minimize the infiltration of these species into the Blackwell Kame through wind and animal dispersion.

## 5.4 CARE AND MAINTENANCE

Care and maintenance is an important factor in the successful growth of trees on landfills. As reported in Dobson and Moffat (1993), Barbour conducted a survey of waste regulation authorities in 1989 in Great Britain, which concluded that the success of tree planting on landfill sites had less to do with the site and tree species characteristics than the degree of maintenance and the selection of suitable planting stock. In turn, Dobson and Moffat (1993) indicated that poor silvicultural practices, such as the use of unqualified and untrained personnel, inappropriate planting stock, and ineffective weed control, resulted in poor success of establishing trees on landfills.

Other factors to be considered when developing trees on landfills include irrigation, fertilization, weed maintenance, and protection from vandalism and animals (e.g. tree shelters, vinyl tree guards, or tree wrap).

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<sup>3</sup> A kame is a low, steep, rounded hill or ridge of layered sand and gravel drift, developed from glacial deposits. Kames were probably formed by streams of melting glacial ice that deposited mud and sand along the ice front. The subsequent retreat of the glacier left them as more or less isolated hills and ridges, ranging in height from a few feet to 100 feet (30 m) or more.

## **6.0 POTENTIAL RESTORATION STRATEGIES FOR THE BLACKWELL LANDFILL**

### **6.1 INTRODUCTION**

The Blackwell Landfill will support a diversity of grass and tree species, and there are no unique combinations of vegetation that would be considered most suitable for the site. Most species of grasses and trees are considered appropriate. However, trees and woody shrubs are only appropriate on those parts of the landfill where there is at least two feet of vegetative soil cover over the clay cap.

The vegetation options described below provide for flexibility in the plant ecosystem that can be developed on the Blackwell Landfill. The options allow for predominantly grass species over the entire landfill, or for woody vegetation on those portions of the landfill that have sufficient thickness of vegetative cover soil. In addition, the options allow for the plant ecosystem to be modified over time, depending upon the long-term development needs of the FPD.

### **6.2 RECOMMENDED VEGETATIVE SOIL COVER THICKNESS**

The vegetative soil cover must be sufficiently thick to accommodate the anticipated root volume and support the tree roots. The case study by Robinson and Handel (1995) (see Case Study No. 2, Section 3.4) demonstrated that one foot of vegetative soil cover was sufficient to support healthy and sustainable growth for several tree species. As well, the root penetration study at the Blackwell Landfill (Section 4.0) indicated that tree roots of healthy were growing in as shallow as 1.3 feet of available vegetative soil cover. However, Gilman *et al* (1981b, 1985) recommends that at least two feet of vegetative soil cover be provided to support tree growth. Therefore, we recommend that at least two feet of vegetative soil cover be provided over the clay cap at the Blackwell Landfill in those areas that are intended to support tree growth. The current locations with known thickness of vegetative soil cover greater than two feet are shown on Figure 5.

If additional vegetative soil cover is required, standard arboreal practice requires that it be permeable to air and water. As well, standard practice suggests that the soils should be placed when dry, and compaction should be avoided. Organic amendments (such as humus, peat moss, manure, crop residues, composted sewage sludge, or refuse compost) will improve the physical, chemical, and biological properties of most cover soil by reducing soil density. As well, the top 4 to 6 inches of the soil cover should consist of topsoil because this is where most of the feeder roots will grow.

### **6.3 WOODY VEGETATION COVER OPTIONS**

The literature review and root penetration study presented earlier in this report indicate that trees are being, and can continue to be, successfully grown on the Blackwell Landfill without

compromising the underlying clay cap. However, development of a healthy, self-sustaining ecosystem requires planning, maintenance, and financial commitment. Therefore, general cover options have been developed which allow the FPD to select the type of plant ecosystem that would be most appropriate for the public's use of the Blackwell Forest Preserve.

The general cover options for the woody plant ecosystems consist of:

- Option 1: Removal of all trees from the landfill;
- Option 2: Removal of unsuitable trees; and
- Option 3: Addition of woody vegetation.

In combination with these woodland options, the cover options for the grass ecosystem consist of Native Prairie or Eurasian Meadow grass species.

#### **6.3.1 Woody Vegetation Option 1: Remove all Trees from the Landfill**

This is an aggressive option that removes all trees and shrubs from the landfill. Any concerns regarding woody vegetation would be thereby eliminated. Disturbed areas would be repaired with suitable grasses.

#### **6.3.2 Woody Vegetation Option 2: Remove Unsuitable Trees**

For this option, all woody vegetation outside of the four defined areas of vegetative soil cover (Figure 5) would be removed from the landfill. Disturbed areas would be repaired with suitable grasses. As well, unsuitable woody vegetation located within the four defined areas of vegetative soil cover would be removed. Unsuitable woody vegetation consists of those that have an invasive nature, competitive with native flora, or are in poor health. Examples of unsuitable trees include *Populus alba* (white poplar), *Elaeagnus umbellata* (autumn olive), *Populus nigra italica* (Lombardy poplar) which is diseased and cankerous (as discussed in Section 4.3), and *Rhamnus cathartica* (common buckthorn) which is invasive. It should be noted that selection of Woody Vegetation Option 2 would result in nearly all trees and shrubs being removed from the landfill.

#### **6.3.3 Woody Vegetation Option 3: Addition of Native Trees**

Option 3 is a variation of Option 2 that would include removal of unsuitable woody vegetation from the four defined areas of vegetative soil cover, and the removal of all woody vegetation from the remaining areas of the landfill. However, the FPD would have the option of expanding the woody vegetation by planting additional trees and shrubs in the four defined areas of vegetative soil cover, or by planting trees and shrubs in new areas of vegetative soil cover at least two feet thick.

This option could also involve removing non-native trees and shrubs from the four defined areas of vegetative soil cover, and planting additional native species.

From an ecological perspective, Wood Option 3 is attractive considering the close proximity of the landfill to the Blackwell Kame, and the current FPD efforts to restore and maintain this Kame.

## 6.4 SUITABLE GRASS SPECIES

Most grass species that are sufficiently hardy for the DuPage County are acceptable for growing on the Blackwell Landfill. However, the grass species must be selected by ecologists familiar with growing conditions on the Landfill.

The recommended grasses for the Blackwell Landfill are Native Prairie species. A Native Prairie would consist of native grasses and wildflowers. This type of ecosystem is naturally stable and self-sustaining. Native plants are supremely suited for the local climatic conditions, and there are a wide variety of species to choose from, which can result in a very diverse system. Native plant communities are often more attractive to a wider variety of mammals, birds and insects (many of which can be rare). The public often finds the Native Prairie ecosystem more interesting due to its diversity. A Native Prairie also resists invasion of derelict grass species if the native system is vast. Prairie grasses ultimately should provide the fuel matrix for maintaining a woody plant or prairie system, but for a greater diversity of species, the native system should contain perennial wildflowers.

The roots of native prairie grasses can grow up to several meters deep in their native soils (Robinson and Handel, 1995). Unfortunately, the environmental conditions (i.e., the soil matrix) under which this root growth occurred was not described. However, as with tree roots, grass roots are expected to grow horizontally in the presence of an underlying confining layer such as a compacted clay cap. To confirm that the compacted clay layer impedes vertical growth of grass roots, a long term monitoring program, as described in Section 7.3.4, is recommended.

A Eurasian Meadow is the typical plant community that is established on landfills today and is the current vegetation at the site. It would be a suitable alternative to native prairie grasses and wildflowers. However, the Eurasian Meadow consists of perennial grasses that are not native to the region. It is a low-diversity system, dominated by perennial Eurasian grasses, and is attractive to only few animal species. If a few Eurasian perennial clovers and wildflowers are included in the mix, it can be a fairly attractive landscape for two to three months per year. Care must be taken when considering a Eurasian plant community because it could be a threat to the integrity of the nearby Blackwell Kame. Examples of suitable Native Prairie and Eurasian Meadow grasses and wildflowers are listed below.

Dominant Prairie Grasses	
<i>Andropogon gerardii</i>	Big Bluestem
<i>Andropogon scoparius</i>	Little Bluestem
<i>Elymus villosus</i>	Hairy Wildrye
<i>Panicum virgatum</i>	Switchgrass
<i>Sorghastrum nutans</i>	Yellow Indiangrass
<i>Sporobolus heterolepis</i>	Prairie Dropseed

Perennial Prairie Wildflowers	
<i>Asclepias tuberosa</i>	Butterfly Milkweed
<i>Asclepias verticillata</i>	Whorled Milkweed
<i>Aster ericoides</i>	Heath Aster
<i>Aster azureus</i>	Skyblue Aster
<i>Aster laevis</i>	Smooth Aster
<i>Aster novae-angliae</i>	New England Aster
<i>Carex bicknellii</i>	Bicknell's Sedge
<i>Carex brevior</i>	Fescue Sedge
<i>Carex molesta</i>	Troublesome Sedge
<i>Coreopsis palmata</i>	Stiff Tickseed
<i>Coreopsis tripteris</i>	Tall Tickseed
<i>Dodecanteon meadia</i>	Pride of Ohio
<i>Eryngium yuccifolium</i>	Button Eryngo
<i>Euphorbia corollata</i>	Flowering Spurge
<i>Galium boreale</i>	Northern Bedstraw
<i>Gentian flavida</i>	Plain Gentian
<i>Gentiana puberulenta</i>	Downy Gentian
<i>Helianthus mollis</i>	Ashy Sunflower
<i>Helianthus rigidus</i>	Rigid Sunflower
<i>Heliopsis helianthoides</i>	Sunflower Heliosis
<i>Heuchera richardsonii</i>	Richardson's Alumroot
<i>Lespedeza capitata</i>	Roundhead Lespedeza
<i>Liatris aspera</i>	Tall Gayfeather
<i>Liatris pycnostachya</i>	Cattail Gayfeather
<i>Liatris spicata</i>	Dense Gayfeather
<i>Parthenium integrifolium</i>	Wild Quinine
<i>Petalostemum candidum</i>	White Prairie Clover
<i>Petalostemum purpureum</i>	Purple Prairie Clover
<i>Phlox pilosa</i> v. <i>fulgida</i>	Downy Phlox
<i>Rosa carolina</i>	Carolina Rose
<i>Rudbeckia hirta</i>	Blackeyed Susan
<i>Rudbeckia subtomentosa</i>	Sweet Cornflower
<i>Sipphium integrifolium</i> v. <i>deamii</i>	Wholeleaf Rosinweed
<i>Silphium laciniatum</i>	Compass Plant
<i>Silphium terebinthinaceum</i>	Prairie Rosinweed
<i>Smilacina stellata</i>	Starry False Solomon's Seal
<i>Solidago juncea</i>	Early Goldenrod
<i>Solidago nemoralis</i>	Dyersweed Goldenrod
<i>Solidago rigida</i>	Stiff Goldenrod
<i>Tradescantia ohiensis</i>	Bluejacket
<i>Viola pedatifida</i>	Prairie Violet
<i>Zizia aurea</i>	Golden Zizia

Perennial Eurasian Grasses	
<i>Agrostis alba</i>	Red Top
<i>Bromus inermis</i>	Hungarian Brome
<i>Dactylis glomerata</i>	Orchard Grass
<i>Festuca elatior</i>	Tall Fescue
<i>Festuca rubra</i>	Red Fescue
<i>Phleum pratense</i>	Timothy
<i>Poa compressa</i>	Canada Bluegrass
<i>Poa pratensis</i>	Kentucky Bluegrass
Perennial Eurasian Wildflowers	
<i>Chrysanthemum leucanthemum</i> var. <i>pinnatifidum</i>	Oxeyedaisy
<i>Coreopsis lanceolata</i>	Lanceleaf Tickseed
<i>Trifolium hybridum</i>	Alsike Clover
<i>Trifolium pratense</i>	Red Clover

## 6.5 SUITABLE TREE SPECIES

Most tree and shrub species that are sufficiently hardy for the DuPage County are acceptable for growing on the Blackwell Landfill. However, the exact species of trees and shrubs that will be grown on the landfill must be selected by ecologists familiar with growing conditions on the landfill. The main criteria when selecting trees and shrubs are that the species must be compatible with its general location on the landfill, and must be compatible with surrounding tree and grass species. General protocols for selection of tree and shrub species are provided in Section 7.0 of this report. The few tree species that are not considered acceptable are those species that are aggressively invasive and competitive, and those species whose canopy blocks sunlight to the growing bottom layer of plants. Examples of these unsuitable tree species include common buckthorn and autumn olive.

Suitable trees for the Blackwell Landfill can be either native or non-native species. However, native species attract more animal species, particular birds for perching and nest building activities, and therefore are recommended. In turn, birds feeding patterns increase the potential for seed dispersal, which is an important mechanism in maintaining woodlands and increasing plant density. Native trees that commonly grow in DuPage County include oaks, hickories, and walnuts. Non-native trees, while still being suitable, can become derelict. Without proper maintenance, non-native trees can increase the potential for cover erosion if undergrowth is allowed to disappear.

Examples of the more common tree species native to DuPage County are provided below.

<b>Suitable Native Trees</b>	
<i>Carya cordiformis</i>	Bitternut Hickory
<i>Carya ovata</i>	Shagbark Hickory
<i>Corylus americana</i>	American Hazelnut
<i>Fraxinus americana</i>	White Ash
<i>Juglans nigra</i>	Black Walnut
<i>Ostrya virginiana</i>	Eastern Hophornbeam
<i>Prunus serotina</i>	Black Cherry
<i>Quercus alba</i>	White Oak
<i>Quercus macrocarpa</i>	Bur Oak
<i>Quercus rubra</i>	Northern Red Oak
<i>Quercus velutina</i>	Black Oak
<i>Quercus coccinea</i>	Scarlet Oak
<i>Viburnum prunifolium</i>	Blackhaw
<i>Tilia americana</i>	American Basswood
<i>Pinus resinosa</i>	Red Pine
<i>Pinus strobus</i>	Eastern White Pine

## **7.0 PROTOCOLS FOR WOODY VEGETATION EXPANSION**

### **7.1 SUITABLE WOODY VEGETATION GROWTH AREAS**

The areas on the landfill that are currently suitable for expansion of woody plants are shown on Figure 5. This figure identifies the four defined areas with at least a two-foot thickness of vegetative soil cover, and existing control structures. However, following completion of cap repairs 1998, the FPD placed considerable thickness of topsoil on parts of the landfill to improve overall site drainage. These areas of new topsoil, if greater than two feet in thickness, will be suitable for establishing additional woody plants. If the FPD chooses to establish woody plants in these areas, the areas must be mapped and the total thickness of soil cover must be established. If the FPD desires to establish woody plants on other parts of the landfill that do not currently have defined soil cover, a minimum of two feet of new vegetative soil cover must be placed in those areas. Suitable new vegetative soil cover consists of uncompacted sandy or silty soils that are covered with a minimum of six inches of topsoil.

### **7.2 DEED RESTRICTIONS**

In 1997 and in accordance with the Unilateral Administrative Order (UAO), the FPD placed a deed restriction on the Blackwell Landfill. This deed restriction bars future development and groundwater use within the landfill boundaries. A copy of the deed restriction is provided in Appendix C. Specifically, the deed restriction states that:

- There shall be no use of, or activity, on the site that may interfere with, damage, or otherwise impair the effectiveness of completed response action, except with written approval of the U.S. EPA.
- There shall be no use of groundwater underlying the site, except with written approval of the U.S. EPA.
- There shall be no residential, commercial or agricultural use of the landfill, including excavation, landfilling, mining, invasive construction and drilling, except with written approval of the U.S. EPA.
- There shall be no tampering or removal of containment or monitoring systems.
- There shall be no activities that cause destruction of vegetation on the landfill that could cause degradation of remedial components.
- There shall be no ignition sources on the landfill, except with written approval of the U.S. EPA.

The restoration plans developed for the Blackwell Landfill, as well as necessary care and maintenance, must comply with all terms of the deed restriction.

## **7.3 RESTORATION STRATEGY**

A restoration strategy will be prepared upon the FPD's selection of the woody vegetation and grassland options for the Blackwell Landfill, and prior to any revegetation efforts. This strategy will be detailed in a follow-up report entitled "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill". This report is scheduled to be submitted to the U.S. EPA by early July 2000. The report will describe the locations where grass and woody vegetation will be developed on the Landfill, as well as specific grass, shrub and tree species. The report will also describe the planting strategy; field verification of the available vegetative layer; woody vegetation implementation; and long-term monitoring. A general description of each component is briefly discussed below.

### **7.3.1 Planting Strategy:**

A planting strategy will be developed to select areas on the Landfill for the planting of grasses or woody vegetation. This strategy will consider:

- The end use scenario;
- Potential windthrow conditions;
- Access to LCS control structures and equipment (vaults, monitoring wells, gas vents, buried leachate or landfill gas conveyance pipes, control buildings and security fences);
- Extreme environmental conditions such as steep slopes; and
- Silvicultural issues including planting techniques, tree spacing, and height and age of trees to be planted.

Plants will be selected with consideration of the following:

- Differences in slope of the landfill and sun exposures;
- The unsuitability of certain trees, shrubs and grasses;
- The rate of tree growth (i.e., slower growing trees have been shown to be more tolerant to landfill conditions than certain rapidly growing species);
- The influence of mycorrhizal fungi; and
- Additional considerations, including mulch, soil amendments, and establishment of the community underneath the canopy of the tree.

In addition, the wetness and the conservatism categories (as described in Section 1.2) will be used to aid in the selection of plant species. The wetness categories will allow selection of species that will thrive in the well-drained conditions on the landfill. The conservatism categories will allow species that are sufficiently tolerant of disturbed soil conditions. Conservatism coefficients between 3 and 6 are considered most suited to the Landfill. Tree species with conservatism coefficients from 7 to 10 are unlikely to survive on the landfill, while species with conservatism coefficients below 2 are inappropriate in that they volunteer over time with the potential to expand coverage to undesired areas.

### **Controlled Burns:**

The planting strategy will also consider the use of controlled burns to control the growth of unsuitable grasses and woody vegetation. Since 1975, controlled burns have been a management technique in place at many forest preserves in the FPD's holdings, as well as other Forest Preserve Districts in Illinois. This is also consistent with management practices at other landfills, such as Settlers Hill Landfill in Batavia, Illinois, and the Woodland Landfill in Elgin, Illinois. Both facilities are Subtitle D and Illinois Part 811 regulated landfills.

Only qualified personnel (trained to meet National Wildfire Coordinating and Group standards) can undertake prescribed burnings. All control structures on and surrounding the landfill must be protected during the burns. Currently, all controlled burns performed by FPD are conducted under IEPA and local fire department permit. Coordination between the DuPage County Health Department, local police, DuPage County Sheriff, and local and adjacent fire department is also maintained during the burn. The U.S. EPA will be given a two-week notice prior to implementation of a controlled burn.

Controlled burns of native grasses are typically easier than mowing and native grasses respond better if they are burned on a regular basis. However, because methane is currently passively vented at Blackwell Landfill through a series of shallow and deep landfill gas vents, the feasibility of conducting prairie burns on the landfill must be thoroughly considered prior to establishing vegetation requiring controlled burns. However, as noted in Section 5.2.3, a draft work plan has been submitted to the U.S. EPA requesting approval to reconfigure LFG emission sources so that the main LFG vent stack becomes the only LFG emission source on the Blackwell Landfill. This reconfiguration would virtually eliminate methane as an ignition source on the landfill.

The LFG sources on the Blackwell Landfill have the ability to be shut off during controlled burns. The main gas vent at the top of Mount Hoy, and the dual leachate and LFG extraction wells, have shut off valves. Should the U.S. EPA approve the proposed re-configuration of LFG emission sources (as described above), shut off valves and secure caps will also be installed on remaining gas vents.

The following will be considered by qualified prairie burn personnel to determine the feasibility of conducting controlled burns at Blackwell Landfill:

- Shape of landfill;
- Amount of moisture in the plant mass;
- Locations of passive gas vents and control structures;
- Fire suppression using pumper trucks;
- Security;
- Area to be burned; and
- Ambient conditions, including wind conditions, humidity, temperature.

### **7.3.2 Field Verification**

Four areas have already been identified on the Landfill that have suitable thickness of vegetative cover (defined in Section 6.2 as a minimum of 2 foot of soil over the clay cap). However, other potential areas for development of woody vegetation will also be examined to determine if they are currently acceptable. Hand augering, drilling, or use of topographic records will be used to determine the thickness of vegetative soil cover layer. Care will be taken not to penetrate the compacted clay cap during any invasive activities. In addition, hand augering will be utilized within 20 feet of the general perimeter of suitable areas to accurately define the extent of suitable planting areas. The FPD will voluntarily conduct these activities, and does not plan to seek Agency input prior to the field verification.

Areas that do not currently have a vegetative cover that meet the two-foot criteria may be amended with the placement of additional vegetative soil. As previously noted, suitable new vegetative soil cover consists of uncompacted sandy or silty soils that are covered with a minimum of six inches of topsoil. A licensed surveyor will document the suitable planting areas.

### **7.3.3 Woody Vegetation Implementation**

Once the areas with suitable vegetative cover have been delineated, the overall planting scheme and implementation plan will be developed and submitted for Agency approval. A formalized planting strategy and implementation plan will include, but not be limited to, the following:

- A map of the landfill indicating areas of planting and species (trees and other vegetation) to be planted;
- The age and number of tree species to be planted;
- Survey staking of the areas to be planted;
- Overall species spacing;

- A planting schedule defining planting seasons;
- Proper silvicultural practices to be employed during planting;
- Weed control and protection from animals and vandalism;
- Fertilization and irrigation;
- Site specific procedures for conducting prairie burns, if burns are determined to be suitable for site conditions. This would include a health and safety plan and a contingency plan developed by qualified personnel, to protect human health, the landfill and its remedial components, and the surrounding environment during controlled burns; and
- Replacement strategy for trees that do not survive the initial implementation.

The implementation plan will also describe the required site preparation activities. For example, unsuitable trees, shrubs and grasses will be identified and marked. The unsuitable vegetation, including viable roots, will then be removed, and the vegetative cover soil repaired and revegetated with replacement trees or grass. Moreover, at this time, soil samples may be analyzed, if deemed necessary by an ecologist, to determine if the soil will need to be amended with nutrients, through application of fertilizer, to promote healthy tree growth. Following site preparation, the woody vegetation would be planted in the specified areas of suitable vegetative cover.

### **7.3.4 Long –Term Maintenance and Monitoring**

The long term maintenance and monitoring program may be described as a three-phase approach, consisting of regular maintenance, periodic evaluation, and documentation, which are detailed in the following sections.

#### **7.3.4.1 Regular Maintenance**

The establishment of a healthy, self-sustaining ecosystem on the Blackwell Landfill will require regular maintenance that will be dependent upon the species and diversity of grasses and woody plants planted on the landfill. The FPD has personnel who have experience maintaining native prairie and woody vegetation.

Scheduled activities for woody vegetation may include, but are not limited to, regular irrigation during extended dry periods, protection from vandalism and animals, pest control, pruning, and mulching of trees as part of regular maintenance activities performed in the rest of the Blackwell Forest Preserve. If windthrow occurs, toppled trees will be identified and removed within a two-week timeframe, weather permitting. Although it is unlikely that windthrow would cause damage to the clay cap, an assessment of potential damage must be made. Appropriate repairs to the clay cap and vegetative cover soil will be made if necessary.

Primary maintenance for a Eurasian Meadow may consist of mowing one to two times a year. Primary maintenance for Native Prairie may consist of mowing one to two times a year, or controlled burns. Mowing would control the establishment of woody plants in undesirable locations on the cover. However, timing of the mowing is important to the survival of any ground-nesting birds; it should not take place before July 15<sup>th</sup> to allow the birds to leave their nests. The aesthetic appearance of the cover would be greatly enhanced if the hay were removed after mowing. Qualified personnel would conduct the controlled burns when appropriate, in accordance with site specific procedures for the protection of human health, the remedial components at Blackwell Landfill, and the surrounding environment.

#### **7.3.4.2 Periodic Evaluation**

Regular assessments of the restoration strategy will be conducted annually and at five-year intervals. The annual assessments will provide qualitative evaluation of the arboreal strategy, while the five-year assessments will evaluate root growth and their impacts, if any, on the integrity of the underlying clay cap. The annual and five-year assessments will provide suggestions for improvement and adjustment to the restoration strategy.

The annual assessments will supplement the ongoing landfill maintenance and monitoring activities. These assessments will note the early success of germination of species, and will include mapping of distressed or dead vegetation, if any. If distressed or dead vegetation is noted, the assessment will include an evaluation of the potential causes of the vegetation distress and death, such as lack of precipitation, vandalism, wildlife grazing, disease, poor planting stock, or possible LFG effects. If deemed appropriate, nutrient levels in the vegetative cover soils will be analyzed (e.g., pH, magnesium, calcium, phosphorus, potassium, nitrate, ammonia, conductivity, copper, iron, zinc, and manganese) and adjusted accordingly through the application of fertilizer.

In addition, successful establishment of a low maintenance, highly diversity ecosystem requires the identification and removal of invasive, non-native grass and tree species that will be detrimental to a woodland environment. In a study conducted by Robinson and Handel (1995), one year after planting 17 different species on Fresh Kills Landfill, birds had introduced 20 new species. The authors believed that the addition of the planted trees added perching locations for fruit-eating birds that would not normally perch below 1.5 to 2 meters. The authors concluded that, in general, for every three installed plants, natural dispersion added a new individual to the community during the first year of the study. Therefore, the areas surrounding woody vegetation establishment will be monitored annually to ensure that grasses and woody vegetation volunteers do not grow outside the area boundaries, and that only suitable species remain. Examples of the invasive grass species include crown vetch (*Coronilla varia*) or bird's foot trefoil (*Lotus corniculatus*). Their weak root system may not be able to prevent erosional gullies from developing.

The annual assessment will be conducted by qualified ecologists familiar with the restoration strategy. Specific procedures for conducting the annual qualitative assessment will be provided in the "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill."

The five-year assessments will evaluate the effects of deep-rooted grasses, forbs, and tree roots on Blackwell Landfill's clay cap. The primary study will be conducted on representative trees and grass species that will be excavated in order to examine root growth and clay cap condition. Trees will be selected for excavation based upon the height, age, and planting density of the tree species. The study will also be conducted on dead or dying trees. If damage to the clay cap exists, the probable cause of the damage will be determined. Once the cause of any clay cap damage has been ascertained, the current vegetation in that area will be re-evaluated, and changes in vegetation types will be conducted during appropriate planting times. Damage to the clay cap will be repaired in accordance with the Operations and Maintenance Plan (Montgomery Watson, February 1999), and documented in accordance with the procedures discussed in Section 7.3.4.3 of this report. The FPD will remove unsuitable vegetation from the Blackwell Landfill should the monitoring program suggest that the vegetation could affect the integrity of the clay cap. Specific procedures for conducting the five-year assessments will be provided in the "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill."

#### **7.3.4.3 Documentation**

The regular maintenance, annual qualitative assessment, and five-year monitoring of the restoration strategy will be documented. The regular maintenance documentation will summarize scheduled, as well as unscheduled, maintenance. The yearly qualitative assessment will document the progress of the restoration strategy, and will provide recommendations and schedule for improvement of the strategy. The five year monitoring report will describe the current grass and woody vegetation conditions on the landfill, provide an overall summary of regular maintenance and the results of the root penetration study, and provide recommendations for the modification of the regular maintenance program and the restoration strategy, including schedule.

## 8.0 UNCERTAINTIES

The Arboreal Study indicates that tree roots on a landfill will not compromise the integrity of an underlying clay cap. However, the available case histories are limited in number and do not cover all possible scenarios that could be encountered on a landfill. Therefore, the arboreal strategy may encounter unexpected future problems. This section describes the uncertainties with the arboreal strategy, the associated problems, and their expected solutions.

### **Emission of Landfill Gas:**

Should roots from grasses, forbs or trees penetrate the underlying clay cap, uncontrolled LFG emissions may occur. These uncontrolled LFG emissions are expected to manifest themselves through distressed or dead vegetation, and odors. If distressed or dead vegetation are observed and unexplained odors are noted during routine maintenance activities, an investigation will be undertaken to characterize the cause and extent of the problem. The investigation could include additional root penetration studies, screening with a photoionization detector (PID), ambient air sampling and analysis, and the installation of shallow gas probes with subsequent sampling and analysis.

If the investigations indicate that uncontrolled LFG emissions are occurring through the landfill cap, the clay cap will be repaired in accordance with the Operations and Maintenance (O&M) Plan (February 1999). If the investigations indicate that the uncontrolled LFG emissions are not caused by the penetration of roots through the clay cap, additional investigations may be conducted in accordance with the requirements of the O&M Plan to determine the actual cause and the required response actions.

If the investigations indicate that the uncontrolled LFG emissions were caused by root penetration of the clay cap, additional root penetration studies may be conducted in other unaffected areas to assess the full nature of the potential problem and to determine which grass, forb and tree species were causing the problems. The restoration strategy for the landfill will be re-evaluated, and the FPD will consider removing the affected species or limiting their growth.

It is important to note that the penetration of grass, forb or tree roots through the clay cap is unlikely. A large number of different grass, forb and tree species are currently growing on the Blackwell Landfill, and there are no known uncontrolled LFG problems on the Site.

### **Leachate Seeps:**

Should leachate seeps occur, the vegetation in the affected areas are expected to die. However, leachate seeps are not currently occurring, and are not expected to occur in the future because the leachate collection system (LCS) installed in 1997 is lowering overall leachate levels in the landfill.

### **Increase in Leachate Generation:**

Should roots from grasses, forbs or trees penetrate the underlying clay cap, additional leachate could be generated as a result of increased infiltration of precipitation. The increased leachate generation could in turn increase leachate levels or increase the pumping rate of leachate extraction wells.

Should regular O&M monitoring indicate either a sustained increase in leachate levels or a sustained increase in extraction rates, investigations will be conducted to determine the cause and location of the problem. If the investigations indicate that the problem is caused by root penetration, the clay cap in the area will be repaired in accordance with the O&M Plan. If cap damage can not be ascertained, the area will continue to be monitored.

If the investigations indicate that the increased leachate generation was caused by root penetration of the clay cap, additional root penetration studies may be conducted in other unaffected areas to assess the full nature of the potential problem and to determine which grass, forb and/or tree species were causing the problems. The arboreal strategy for the landfill will be reevaluated, and the FPD will consider removing the affected species or limiting its growth.

Should an area of landfill cap be repaired, the area will be monitored to determine whether the existing leachate extraction system will remove the additional generated leachate. Should the monitoring suggest that the existing leachate extraction cannot remove the additional leachate, consideration will be given to the installation of temporary leachate extraction points in the affected area.

### **Damage from Controlled Burns:**

There is a possibility that LFG emissions may ignite during a controlled burn on the Blackwell Landfill. However, the risk of this occurring can be minimized by temporarily closing LFG shut off valves on LFG vents and extraction wells, by capping other LFG vents not controlled by valves, and by tightening loose connections on the LFG conveyance lines. All LFG emission sources will be inspected following a controlled burn to confirm that there was no accidental ignition of LFG. Any LFG fires will be put out with fire extinguishers or other appropriate means.

In spite of controls to be placed on the implementation of controlled burns, landfill remedial components, such as LCS and LFG vaults, may become damaged by fire. Should this occur the damage components will be repaired or replaced, and the burn procedures and controls will be re-evaluated to determine improvements. However, should the re-evaluation indicate that the improved burn procedures and controls will not minimize damage, the FPD will consider a permanent ban on controlled burns, and the use of mowing to control the growth of unsuitable grasses and woody vegetation.

### **Windthrow:**

Windthrow was previously discussed in Sections 3.3 and 7.3 of this report. Should windthrow become a persistent problem, the FPD will consider the removal of trees from windthrow affected areas and removal of specific species that appear to be more susceptible to windthrow.

**Increased Potential of Slope Failure:**

Slope failure is not expected to occur. The Blackwell Landfill is currently covered by Eurasian grasses that do not have extensive root masses that would tend to bind soils together, and slope failure is not occurring. The possible replacement of Eurasian grasses with Native grasses will be expected to increase the overall root mass, and increase slope stability.

## 9.0 CONCLUSIONS

The purpose of this Arboreal Study was to present a conceptual evaluation of tree growth on landfills, and to demonstrate that if properly selected and implemented, trees will not harm the integrity of the existing clay cap at Blackwell Landfill. The study consisted of a literature review, a multiphase root penetration study, and a review of current growing conditions on the Landfill. The study concluded that a minimum of two feet of vegetative soil cover is required to support tree growth and protect the integrity of the underlying compacted clay cap. The study also identified four areas on the Landfill that currently have a sufficient thickness of vegetative soil cover to support tree growth, although additional areas of suitable soil cover could be identified by further investigative activities or through the placement of additional soil.

The Arboreal Study identified three potential restoration strategies for the Landfill. They are:

- 1) removal of all woody vegetation currently growing on the landfill;
- 2) removal of all unsuitable vegetation from the landfill. This would include the removal of unsuitable species from the areas of sufficient soil cover thickness, and removal of all woody vegetation from the remaining areas of the Landfill that do not have sufficient soil cover thickness; and
- 3) establishment of additional woody vegetation on the landfill in areas of sufficient soil cover thickness.

Since the FPD has not yet received approval for this concept, the FPD has not yet selected an end use scenario for the Blackwell Landfill. Once the U.S. EPA has approved the concept, the specific restoration details, such as the type and number of species to be planted, specific forest and meadow prairie community types, and their planting locations, will be planned. This information will be developed with consideration of landfill topography, potential windthrow issues, locations of existing landfill control structures and equipment, areas with acceptable vegetative cover thickness, and potential maintenance concerns, and will be presented in a follow-up report entitled "Comprehensive Restoration Strategy for the Revegetation of the Blackwell Landfill".

In addition, while the Arboreal Study indicate that tree roots on a landfill will not compromise the integrity of an underlying clay cap, the available case histories are limited in number and do not cover all possible scenarios that could be encountered on a landfill. Therefore, as part of the follow-up report, a comprehensive monitoring program will be developed to monitor vegetal growth and to verify that the future integrity of the clay cap over the Blackwell Landfill will not be compromised. Should information from the monitoring program suggest that certain woody vegetation could affect the integrity of the clay cap over the Blackwell Landfill, the inappropriate woody vegetation will be removed from the landfill.

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**Appendix A**  
**Woody Species Report for the Blackwell Forest Preserve Landfill Site (Conservation**  
**Design Forum)**

**Appendix B**  
**Thickness of Soil Cover - Details**

**Appendix C**  
**Deed Restrictions**

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**Volume I of II**

**DRAFT FINAL  
ARBOREAL STUDY REPORT**

**BLACKWELL FOREST PRESERVE LANDFILL SITE  
DUPAGE COUNTY, ILLINOIS**

**Montgomery Watson File No.: 1252008**

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**Prepared For:**

**Forest Preserve District of  
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**November 1999**



**MONTGOMERY WATSON**

**DRAFT FINAL  
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**Prepared For:**

**Forest Preserve District of  
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11/15/99  
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Appendix B	Thickness of Soil Cover (Detailed)

Appendix C Deed Restrictions

**Volume II of II:**

Appendix D Literature Search

## **1.0 INTRODUCTION**

This Arboreal Study Report has been prepared by Montgomery Watson on behalf of the Forest Preserve District (FPD) of DuPage County, Illinois, and presents an evaluation of tree growth on the integrity of the existing landfill cap at the Blackwell Landfill in DuPage County, Illinois (Site). This report also presents woody vegetation cover options that identify grass and woody vegetation, endemic to DuPage County, which can be safely planted on the landfill without damaging the underlying landfill cap.

The Arboreal Study has been conducted to meet the requirements set forth in the March 7, 1996 U.S. EPA Administrative Order by Consent (AOC) and Statement of Work (SOW), Docket No. V-W-'96-C-341. The AOC and SOW state that root penetration from trees shall not allow percolation of rainwater through the refuse within the landfill. The AOC and SOW also state that the FPD shall develop a rationale for acceptable vegetative cover thickness in combination with specific tree types, and shall develop a tree management program that will not threaten the integrity of the landfill cover.

The purpose of this Arboreal Study Report is to present an evaluation of tree growth on landfills, and to demonstrate that if properly implemented, trees will not harm the integrity of the existing landfill cap at Blackwell Landfill. The evaluation was conducted through a literature review<sup>1</sup>, a multiphase root penetration study, and a review of current growing conditions on the Landfill. This report also provides woody vegetation cover options for the Landfill and protocols for woody vegetation expansion. However, because an end use has not yet been chosen for Blackwell Landfill, specific details, such as the type and number of species to be planted and specific forest and meadow/prairie community types, have not been selected. These details will be developed in a follow up report entitled "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" that will be submitted prior to any revegetation efforts. The expected contents of this future report are described in a latter portion of this report.

### **1.1 BACKGROUND**

The Blackwell Landfill is located within the Blackwell Forest Preserve approximately six miles southwest of downtown Wheaton, Illinois in Section 26, Township 39 North, Range 9 East, DuPage County, Illinois (Figure 1). The Blackwell Forest Preserve encompasses 1,200 acres of woodlands, grasslands, wetlands and lakes, with the landfill covering approximately 40 acres in the central part of the preserve (Figure 2).

#### **1.1.1 Landfill Construction**

The Blackwell Landfill is located adjacent to an abandoned gravel pit that was purchased by the FPD in 1960. The land was purchased with the intent to create a large hill that could be used by the public for recreational purposes. The FPD began construction of the landfill in 1965, and accepted the final load of refuse in 1973. By the time final contouring and landscaping was completed in 1975, forty to sixty feet of clay were placed on top of refuse on the southwest side

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<sup>1</sup> Copies of most referenced documents are provided in Appendix D

of the landfill to create Mount Hoy. Mount Hoy was finished at an elevation of 839 feet above mean sea level (MSL), approximately 150 feet above the surrounding natural topography. Other areas of the landfill were covered with 2 to 15 feet of predominantly clay cover. In some areas, a vegetative cover of varying sand, gravel and clay composition was placed. A final layer of clayey topsoil (minimum of 4 to 6 inches thick) was installed and vegetated. The final topography of the Site as of 1992 is shown in Figure 3.

The Blackwell Landfill contains approximately 1.5 million cubic yards of refuse classified as general household refuse and light industrial waste. The construction of the hill also includes an equal volume of natural soil fill.

### **1.1.2 Post-Construction History**

In March 1986, the United States Environmental Protection Agency (U.S. EPA) evaluated the Site using the Hazard Ranking System (HRS). A composite score of 35.57 (above the 28.5 threshold for NPL listing) was assigned, with the following scores assigned to each potential route: Surface Water 0.0; Air 0.0; and Groundwater 61.54. The Site was proposed for inclusion on the National Priorities List (NPL) in the Federal Register, Volume 53, Number 122, dated June 24, 1988. The Site received final listing on the NPL in the Federal Register, Volume 55, Number 35, dated February 21, 1990. Subsequent to the final listing on the NPL, a Remedial Investigation/Feasibility Study (RI/FS) was performed at the landfill.

The AOC set forth the required response actions at the Site, which included:

- Delineation of the limits of waste at the landfill edges;
- Cap characterization to delineate areas which did not have two feet of low permeability soil over refuse;
- Repair of those portions of the landfill cover that had less than two feet of low permeability soil over refuse;
- Regrading to promote surface water drainage off the landfill;
- Installation of a leachate collection system (LCS);
- Installation of a passive landfill gas (LFG) venting system;
- Treatment of landfill leachate ; and
- Monitoring of groundwater and system performance.

The required response actions have been completed, or are part of ongoing operation and maintenance.

### 1.1.3 Scope of Study

The required scope of the Arboreal Study was outlined in the U.S. EPA approved Remedial Design Work Plan (Montgomery Watson, April 1996). This Work Plan required: 1) a literature review on the influence that trees and other woody vegetation have on the landfill environment; 2) a field investigation to determine the distribution and depth of the root systems of existing trees on the landfill; and, 3) development of a tree and woody vegetation management plan.

The Arboreal Study was conducted in general accordance with the Work Plan. However, slight modifications to the field investigation were made due to field conditions. Details of these modifications are provided below:

- The Work Plan was based upon the premise that some areas of the landfill may not have a clay cap over refuse. Therefore, the Work Plan provided for three locations on the landfill where existing tree root systems would be evaluated. These locations were to include: a typical depth of vegetative soil cover over a clay capped area, a shallow depth (1 to 2 meters) of vegetative soil cover over refuse, and a deeper depth (2 or more meters) of vegetative soil cover over refuse. However, subsequent investigations indicated that only four areas of the landfill did not have an adequate clay cap over refuse (Montgomery Watson, January 1997), and these four areas were subsequently repaired in 1997 and 1998 by construction of a minimum 2 foot thick compacted clay cap (Montgomery Watson, 1999).

At the time of the arboreal field investigation (December 1998), all areas of the Blackwell Landfill had a clay cap over refuse. Therefore, the field investigation was only able to evaluate existing tree root systems in areas that had vegetative soil cover over a clay cap.

- The Work Plan provided for collection and analysis of soil samples to determine if biologically significant chemical and physical differences in the soil profile had influenced root distribution and rooting depth. However, a site reconnaissance performed in October 1999 indicated that the existing chemical profile in the cover soils was already permitting healthy tree growth, and that collection of chemical data would not provide additional information. As well, considerable information on physical soil information was collected during a predesign investigation (Montgomery Watson, 1997) completed after the Work Plan and prior to the Arboreal Study, and this information was used in lieu of collecting new physical soil data. However, soil chemical data may be collected as part of the future "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill" report to confirm that conditions are appropriate for tree growth.
- The Work Plan required that the "root systems of two or more specimens of the same species be excavated to determine the root distribution within the soil profile and the overall depth of the root system." However, as described in Section 4.4 of this report, two of the species studied, the eastern red cedar and the slippery elm, had only one specimen growing within the study area. Therefore, replicate specimens could not be studied.

- The Work Plan required that the Arboreal Study would “involve the development of a tree and woody vegetation management plan for the Blackwell Landfill.” As stated in Section 1, the end use for Blackwell Landfill has not yet been developed. Therefore specific details on the types of woody vegetation to be established has not been determined. Greater detail will be presented in the future report entitled “Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill.”

## 1.2 CURRENT VEGETATIVE CONDITIONS

The current vegetative conditions on the Blackwell Landfill were assessed by Conservation Design Forum (CDF) during a September 23, 1999 field reconnaissance. The purpose of the field reconnaissance was to:

- Generally identify the current tree species over the entire landfill, and provide an estimate of their population;
- Generally describe the health of the different tree species, based upon visual observations only; and
- Note the approximate location and size (i.e., tree height and diameter) of what visually appears to be the largest tree, per species, on the landfill.

CDF determined that most of the trees and shrubs volunteered from seed and vegetative propagation. Only a few pine trees were planted after the landfill was closed. The average age of the woody growth is approximately 10 to 15 years old, and none represents remnant vegetation. CDF also identified fourteen areas (i.e., units) where trees were currently growing on the landfill (Figure 4). The woody vegetation present in each unit is described in detail in Appendix A.

CDF identified a total of 27 species of woody plants (trees and shrubs) on the landfill. Fifteen species (56%) are native to this region, with twelve species (44%) considered non-native. Approximately 250 individual woody plants were noted growing on the landfill with diameters at breast height (DBH) greater than two inches. The DBH is defined as the tree diameter at 4.5 feet above ground surface. The most common woody plants, and their approximate population on the Site, is listed below:

Tree Name	Present Number Of Trees*	Tallest Tree Dbh/height
Green Ash ( <i>Fraxinus pennsylvanica subintegerrima</i> )	92	12"/25'
White Pine ( <i>Pinus strobus</i> )	39	12"/25'
Lombardy Poplar ( <i>Populus nigra italica</i> )	35	8"/25'
Honey Locust ( <i>Gleditsia triacanthos</i> )	22	8"/25'
Box Elder ( <i>Acer negundo</i> )	17	8"/25'
Red Cedar ( <i>Juniperus virginiana crebra</i> )	12	3"/10'
Silver Maple ( <i>Acer saccharinum</i> )	12	6"/20'
White Ash ( <i>Fraxinus americana</i> )	10	4"/20'
Black Locust ( <i>Robinia pseudoacacia</i> )	5	8"/25'
Eastern Cottonwood ( <i>Populus deltoides</i> )	3	14"/25'
Scotch Pine ( <i>Pinus sylvestris</i> )	2	5"/12'
Red Oak ( <i>Quercus rubra</i> )	1	4"/20'
Common Buckthorn ( <i>Rhamnus cathartica</i> )	Saplings	-
Scarlet Hawthorn ( <i>Crataegus coccinea</i> )	Grove	-
Smooth Sumac ( <i>Rhus glabra</i> )	Thicket	-
Staghorn Sumac ( <i>Rhus typhina</i> )	Thicket	-

\* greater than two inch DBH

Most of the Lombardy poplars (the third most common tree on the Landfill) were in poor condition, or were dead. While lombardy poplars can grow 70- to 90-feet tall in 20 to 30 years, they seldom attain this growth due to a canker disease (*Dothichiza populnea*) that develops in the upper branches and trunk. Currently, there is no cure for this particular canker disease.

A total of 57 species of herbaceous plants were recorded on the landfill. Of these, 22 species (39%) are native and 35 species (61%) are non-native. The most prevalent herbaceous species are non-native grasses, including tall fescue, perennial rye, and Kentucky blue grass.

The plant inventory on the landfill was characterized according to U.S. Fish and Wildlife Service protocols to determine their likelihood of being found in wetland or upland areas. The plants on the Blackwell Landfill achieved an average "mean wetness value" of 2.35, which corresponds to a facultative upland environment (i.e., a preference for non-wetlands). Further information on the "mean wetness value" and U.S. Fish and Wildlife Service protocols are found in Appendix A.

In addition, the plant inventory was characterized according to their floristic quality to establish whether the plants represented species that prefer natural or disturbed habitat. The assessment was based upon the characteristics of Chicago region plants, as discussed in *Plants of the Chicago Region, 4<sup>th</sup>* (Swink and Wilhelm, 1994). The resultant assessment yielded a coefficient of conservatism (C) of 0.8, indicating that the current vegetation on the Blackwell Landfill is a degraded or derelict plant community. Further information on the floristic quality assessment is found in Appendix A.

### **1.3 REPORT PRESENTATION**

The report is presented in the following eight sections:

- This section, Section 1 presents the purpose of the Arboreal Study and describes the current conditions at the Blackwell Landfill;
- Section 2 describes the benefits of woody vegetation on the stability of landfills;
- Section 3 summarizes a literature review of tree growth studies on landfills and presents various case studies;
- Section 4 presents the results of root penetration study conducted on the landfill on tree species common to the DuPage County Area. The purpose of this study was to demonstrate that the root systems of trees and woody shrubs currently growing on the landfill have not penetrated the underlying clay cap;
- Section 5 summarizes factors necessary to establish and sustain a healthy woody plants on landfills;
- Section 6 presents the woody vegetation cover options for the Blackwell Landfill;
- Section 7 presents the protocols for woody plant expansion;
- Section 8 presents the conclusions of the Arboreal Study; and
- Section 9 contains a list of references.

## 2.0 BENEFITS OF WOODY VEGETATION

Closed landfills represent significant expanses of land and their conversion into recreational areas such as parks and nature centers, is growing increasingly appealing to communities. However, the overwhelming majority of closed sanitary landfills presently utilize various grass species as a final vegetative cover. For closed landfills that are open to frequent public viewing, such as the Blackwell Landfill, the typical 'green dome' landfill feature presents an undesirable appearance. These grass monostands are not ecologically diverse and are expensive to maintain. Without proper maintenance, weed intrusion may invade and dominate the vegetal cover, and cause further deterioration of the landfill's appearance, as weeds grow unabated. However, the undesirable appearance of landfills may be softened by the placement of well-managed and attractive woodland vegetation.

The charter of the FPD is *"to acquire...and hold lands...for the purpose of protecting and preserving the flora, fauna and scenic beauties...for the purpose of the education, pleasure and recreation of the public."* Restoration of the Blackwell Landfill to native woody vegetation and prairie grasses is within the FPD charter, and will enable the landfill to become aesthetically pleasing and blend in with the surrounding forest preserve. In addition, restoration of the Blackwell Landfill will allow the landfill to act as a wildlife corridor and become haven for endangered and threatened plant species.

In addition to public perception, woody vegetation will provide measurable benefits to the overall stability of the soil cover over the landfill, through:

- Erosion control of the soil cover through physical bonding of soil in the root zone;
- Side slope stability where woody plants prevent mass-movement or sliding of soil through mechanical reinforcement and control of soil moisture;
- Reduced net rainfall on the landfill through interception of rainfall on leaves and branches of trees (Dobson and Moffat, 1963); and
- Reduced infiltration potential by evapotranspiration from trees.

The development of woody vegetation on landfills is already occurring in the state of Illinois with the approval of the Illinois Environmental Protection Agency (IEPA). For example, the FPD's Greene Valley Landfill (Woodridge, Illinois) has recently received approval from IEPA for the revegetation of the final cover to native prairie grasses and tree species. The revegetation program consists of replanting several portions of the landfill with differing forest and community types interconnected with numerous recreational trails. These community types, including oak woodland and savanna, are consistent with the surrounding flora of the 1,425 acre Forest Preserve.

The redevelopment and reuse of Superfund sites has been supported by the U.S. EPA. A number of U.S. EPA documents indicate that the reuse of Superfund sites is a priority, and that reuse can

include industrial/commercial, recreational or ecological projects. The U.S. EPA's Superfund Reforms Annual Report for FY1998 provides examples of recreational and ecological projects that include athletic fields, community parks, and habitat preserves. The FPD's desire to maintain woody vegetation on the Blackwell Landfill will enhance the public's use of the Blackwell Forest Preserve, and will allow the development of a diverse plant and animal ecology within the Preserve. While the U.S. EPA's primary priority at the Blackwell Landfill is to maintain the integrity of the selected remedy for the site, which includes the integrity of the clay cap, the FPD believes that the development of woody vegetation on the Blackwell Landfill will not damage the integrity of the clay cap, and will therefore be consistent with U.S. EPA objectives for Superfund sites.

### 3.0 GENERAL CONCERNS

The establishment of woody plants on sanitary landfills has been discouraged by regulatory agencies on capped landfill sites due to several misconceptions. These misconceptions are centered on the belief that the integrity of the landfill cap could be compromised by:

- penetration of tree roots through a landfill cap;
- by desiccation from tree roots extracting moisture from the cap; or
- by high winds over topping trees thereby exposing and tearing the cap (i.e., windthrow).

However, a literature review<sup>2</sup> of these concerns has indicated that the integrity of the landfill cap will not be compromised if tree growth is properly implemented and managed. Details of these concerns are discussed in more detail in the following sections.

#### 3.1 ROOT PENETRATION

The function of a landfill cap is to retard water infiltration thereby minimizing leachate generation. Popular belief is that most trees have a deep-rooted system that can penetrate a clay cap, thus compromising the control of water infiltration into the waste. However, the literature review has indicated that tree root penetration of a landfill cap is unlikely.

The architecture, or shape, of root systems is influenced by tree species. Only a small percent of tree species, such as oak, pine, and fir have a large taproot (i.e., the largest root located immediately beneath the tree trunk). However, even in these species, the taproot diameter typically decreases rapidly as secondary roots branch from it (Dobson and Moffat, 1993). In the majority of species, the dominance of the taproot is lost early in development (Dobson and Moffat, 1993).

In the majority of tree species, the lateral roots assume the greatest functional significance. They provide stability, serve as conducting vessels for the nutrients and water absorbed by the smaller roots, and serves as storage organs for the products of photosynthesis (Dobson and Moffat, 1993). These lateral roots may extend outwards from the trunk a distance of between one and three times the height of the tree.

Wagg (1967) conducted a study to evaluate the influence of soil properties, site modification, and spatial organization of roots during growth of white spruce (*Picea glauca*) in central Alberta, Canada. The trees studied ranged from 31 to 88 years old and 18- to 33-feet high. The roots and their origins were thoroughly classified, as well as the surrounding soil characteristics. Four root forms were identified, as summarized below:

- Elongated Taproot: No change in the root form occurs, all roots grow at similar rates, and secondary roots do not develop.

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<sup>2</sup> Copies of most referenced documents are provided in Appendix D.

- **Restricted Taproot:** Growth restriction occurs due to either soil texture, structure, moisture and frost, or because of rapidly growing lateral roots.
- **Monolayered:** Originate from seedling system in which the taproot is either aborted, contorted and aborted, or degenerated at the rootstock.
- **Multilayered:** Development of secondary roots in response to pronounced site conditions.

Wagg (1967 ) found that the elongated taproot form occurred in well-drained aeolian sands, and were large and well-defined. However, the author noted that spruce exhibiting elongated taproots without secondary roots are uncommon. Instead, the taproot was usually restricted and branched at variable depths. The author stated that the growth of the taproot and other roots may be aborted, restricted or contorted by textural changes between soil horizons or restricted by compaction of the underlying soil. The development of secondary roots may also limit the growth of the taproot and therefore limit its overall importance.

Rooting depth studies, conducted in soils without a near subsurface confining layer such as clay or other low permeable material, indicate that for many species of trees, approximately 90% of all tree roots, and virtually all the larger roots, are found in the upper 2 to 3 feet of soil (Dobson and Moffat, 1993). In addition, the number, length, or surface areas of fine and very fine roots diminish rapidly from the surface with depth (Stone and Kalisz, 1991).

Other rooting depth studies indicate that soil aeration and compaction control root depth. These factors are discussed in greater detail in the following sections.

### **3.1.1 Aeration**

The main factor controlling root growth is aeration. Roots require sufficient oxygen for respiration, although the minimum oxygen concentration required for root growth has not been clearly defined (Dobson and Moffat, 1993). Taylor (1971) reported that a reduced oxygen supply almost instantaneously halted root growth, while Dobson and Moffat (1993), reported that in a study published in 1991 by Kozlowski, root growth is greatly restricted when soil oxygen content drops below 10%, and ceases when soil oxygen drops to approximately 3% - 5%.

Dobson and Moffat (1993) reported that in a study published by Yelinosky in 1964 that oxygen concentrations decrease and carbon dioxide concentrations increase with soil depth. Several studies (Flower *et al*, 1978, Gilman *et al*, 1981b, Leone *et al*, 1979), concluded that high concentrations of carbon dioxide may impede or halt the growth of root systems. As well, Leone *et al* (1979) concluded that root damage from carbon dioxide is different from the root damage from a lack of oxygen. However, the mechanism by which carbon dioxide damages plant roots is not known.

A case study of tree growth on a landfill with high carbon dioxide and methane concentrations in the soil is presented Case Study No. 1 in Section 3.4 of this report.

### 3.1.2 Soil Compaction Within the Root Zone

Soil compaction plays a very important role in aeration and root growth, as well as stability of a growing tree. Soil compaction controls the availability or exposure of oxygen to the root surface, and can physically impede root growth.

In order to grow, tree roots must physically push aside rocks and soil, and must deform sufficiently to penetrate through an available void (Taylor and Gardner, 1960). The ability for a root to penetrate the soil is a function of the soil strength and soil porosity, including the size, continuity, and tortuosity of the voids within the soil (Taylor and Gardner, 1960 and 1963). In addition, the available room for root growth is restricted by the amount of soil pore spaces that are large enough to sustain root growth (Taylor and Gardner, 1960). Studies by Robinson and Handel (1995) indicate that typical extending root tips have a diameter of 0.1 to 3.0 mm while typical soil pore diameters range from 0.002 to 0.2 mm. Pure clay has even lower pore diameters. In addition, studies by Atwell (1993) indicated that in general, roots that are too thick to find a tortuous path between packed soil particles are likely to find an easier passage through the soil by expanding radially and filling the soil axially. As well, root tissues appear unable to thicken in response to mechanical impedance once primary root growth has ceased.

Several studies have also shown that a high degree of soil compaction reduces root growth because tree roots do not maintain growth if they cannot exert enough root growth pressure to push through the soil (Gilman and Leone, 1981, Robinson and Handel, 1995, Dobson and Moffat, 1993). Root growth pressure is defined as the stress acting normally to the root surface which a root must exert to deform the soil around it (Dexter, 1987). It is a function of oxygen concentration, soil temperature, soil moisture, soil compaction, and the degree of root anchorage in the soil.

Taylor and Ratliff (1969b) conducted a study to determine the effects of soil water content and soil strength on the root length of cotton and peanut plants. In short term experiments, their results illustrated that the roots of both plants grew faster at lower soil compaction values. High compaction decreased the root length, although it did not affect the root volume. Additionally, root elongation rates as a function of soil strength were not affected by soil water content. In a comparable study conducted with cotton seedlings, Taylor and Gardner (1963) similarly concluded that an increase in soil strength not only reduced the percentage of roots penetrating the soil, but also decreased root growth rate.

Heilman (1981) conducted a study to identify the upper limit of soil compaction that would cease root penetration, and to determine the relationship between root growth and soil density. His study of Douglas-fir (*Pseudotsuga menziesii*) seedlings concluded that relatively minor increases in soil density may have significant adverse effects on tree seedlings. Total penetration and vertical penetration of primary roots decreased linearly in soil with bulk densities in the range of 85.3 lb/ft<sup>3</sup> through 110.3 lb/ft<sup>3</sup>, while growth was restricted with soil bulk densities ranging from 109.0 lb/ft<sup>3</sup> through 114.0 lb/ft<sup>3</sup>. Observations of root growth patterns in the compacted soil environments showed that the roots grew laterally along the interface of the compacted soil, which may indicate an adaptation of the root architecture to compensate for restricted vertical rooting. (NOTE: A comparison of bulk densities measured within the Blackwell Landfill clay cap is provided in Section 4.1.)

As reported in Dobson and Moffat (1993), Bowen published a study in 1981 that determined that heavier soils restricted root penetration at lower bulk densities than lighter soils, and that dense soils, such as compacted clay, provide barriers due to limited available pore space for root growth.

The soil fabric, or environment, is also a major contributor to the root's physical behavior, and controls water, heat, aeration, and strength relationships that are important for determining overall root growth (Taylor, 1971). Based on a data summarization of 49 families, 96 genera, and 211 species, Stone and Kalisz (1991) reported that root branching is constrained by the patterns of joints, bedding planes, or other voids in the soil environment. Moreover, unfissured dense layers, poorly aerated horizons or water tables are barriers to deep root penetration (Stone and Kalisz, 1991). In addition, if no cracks in a vertical physical barrier are encountered, the roots are diverted laterally and may continue to grow horizontally along the surface until growth conditions change (Taylor, 1971). Under similar conditions, misshapen, but physiologically active, roots may grow in response to soils high in clay content (Taylor, 1971).

### **3.2 CAP DESICCATION**

Damage to the integrity of a landfill cap due to vegetation induced cap desiccation is often raised as a concern on landfills. The basis for this concern is that if tree roots were growing in or on top of a clay cap, water uptake from the roots may cause the clay cap to desiccate and crack. This in turn could lead to increased infiltration of precipitation into the landfill, and the release of landfill gas from the landfill. However, tree roots are not considered a contributor to potential cap desiccation because of the roots inability to penetrate a compacted clay (as described above), and because a physical limitations on the amount of water that tree root systems can remove.

Cap desiccation due to water uptake by tree roots implies that the roots could physically remove enough water to cause cracking of the clay cap. This would be accomplished through direct absorption of water by roots in contact with the cap. However, studies on moisture uptake by tree roots indicate that tree roots can only exert approximately 1.0 MPa to 1.5 MPa of moisture tension in soil (Reeve and Hall, 1978, and Bronswijk, 1991). Bronswijk concluded that desiccation cracking in clayey alluvial subsoils was not observed until moisture tensions exceeded approximately 4.0 MPa. Moreover, as reported in Dobson and Moffat (1993), Gregory published a study in 1988 that showed water uptake by plants is severely restricted at tensions as low as 1.0 MPa. Therefore, since tree roots create only half as much tension needed to cause cracking, tree roots are unlikely to cause cap desiccation.

### **3.3 WINDTHROW**

Potential windthrow damage to landfill caps is caused by the overtopping and uprooting of trees, which in turn can expose or otherwise tear the underlying cap. As reported in Dobson and

Moffat (1993), a study by Schaetzl *et al* in 1989 defined windthrow as, “the technical term for trees being blown over by strong winds, and it can involve snapping of the trunk or uprooting.”

Landenberger (1997) has defined a number of conditions that determine the potential for windthrow. These conditions include the windiness of the climate region, elevation, topography, soil conditions, rooting depth, the tree’s physical crown and stem condition, the tree’s position in the canopy, the canopy’s density, the surface and subsurface soil conditions, past disturbances, and the wind direction, speed, and duration.

Elevation effects on windthrow are coupled with mean wind speed and gale frequency. At higher elevations, winds are typically stronger than in low-lying areas. Therefore, trees at higher elevations are more susceptible to windthrow than those at lower elevations. Topography also is an important factor in determining windthrow potential. The relative exposure of a tree or group of trees is a function of the degree of provided shelter. At high elevations, trees are less likely to be toppled if surrounding high areas shelter them. Similarly, surrounding high points protect lowland trees.

Another critical factor in determining windthrow involves soil condition. Trees growing on wet soils are more likely to be uprooted than those on drained sites. This is due to high moisture decreasing soil cohesion and soil strength (Dobson and Moffat, 1993). Conversely, windthrow potential decreases when tree roots are anchored in frozen soil (Peltola, 1995). Moreover, stony soil tends to provide less soil cohesion than stone-free soils (Dobson and Moffat, 1993).

Windthrow hazards may be reduced if trees are planted in stands rather than singular individuals. Common silvicultural, or forestry, practices suggest that trees in unthinned stands will be more stable than trees planted in thinned stands (Dobson and Moffat, 1993). This was confirmed by observations of trees toppled by Hurricane Donna (Trousdel *et al*, 1965). The high winds did heavier damage in thinned stands of loblolly pines than in unthinned stands. In addition, Peltola (1995) observed that trees growing along a stand edge are subjected to greater wind loading than trees within a given stand.

Windthrow hazards may also be reduced if smaller trees are utilized. A smaller tree will have less total area exposed to the wind than a larger tree because the total exposed crown area will be reduced, and if toppling occurs, a smaller tree will have a proportionally smaller amount of disturbed soil (Dobson and Moffat, 1993). This was confirmed by a modeling experiment conducted by Peltola (1995) where the windspeed required to topple a tree decreased as the height to diameter ratio, the crown to stem weight, or the tree size increased.

### 3.4 CASE STUDIES

The following case studies provide a discussion of the adaptation of root architecture and growth patterns found at three sanitary landfills in the eastern United States. These studies indicate that the tree root system has the ability to adapt to limited soil cover and an underlying compacted clay barrier.

#### Case Study 1: Edgeboro Landfill, East Brunswick, NJ

Gilman *et al* (1981a) conducted a study of the Edgeboro Landfill, completed in 1966. Between 6 and 9 inches of soil had been placed over the municipal refuse as a final cover. The authors added 1 foot of sandy subsoil and approximately 6 to 9 inches of additional topsoil to increase the total depth of vegetative cover to approximately 2 feet. This amended landfill cap did not act as a barrier to landfill gas, and carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) diffused through the cover. A control plot was established one-quarter mile from the landfill plot in undisturbed woodland. In order to replicate landfill soil conditions, the control plot was amended with additional sandy soil and topsoil. Nineteen woody species, including pin oak (*Quercus palustris*), American basswood (*Tilia americana*), green ash (*Fraxinus pennsylvanica*) and honey locust (*Gleditsia triacanthus*), were planted on both experimental plots and were evaluated for their ability to tolerate the landfill's soil conditions.

The study determined that there was an inverse relationship between landfill gas concentrations and total root growth. In landfill areas with high landfill gas concentration, 35% of tree roots were located in the top 6 inches of soil. In landfill areas with low gas concentrations, only 3.8% of roots were located in the top 6 inches. In many instances, tree roots were able to adapt their root architectures to avoid high gas areas. For example, a honey locust planted on the landfill grew an approximately twelve foot long lateral root that originated 2-inches below ground surface and remained at this depth throughout its entire length.

As well, the tree root systems on the landfill (in areas with both high and low gas concentrations) had significantly shallower root systems than trees growing on the control plot. For example, ash seedlings growing on the control plot exhibited roots that were twice as long and deep as seedlings growing on the landfill. In addition, the control plot seedlings grew almost vertically and did not exhibit the matted, shorter root zone of the landfill seedlings.

However, tree species that naturally produce shallow root systems were able to grow well on the landfill plot. Gilman *et al* (1981a) concluded that oxygen levels in the soil and the availability of the oxygen significantly effected the depth of the roots. The authors suggested that landfill gases be minimized in the root zone to promote healthy vegetation growth.

#### Case Study 2: Brookfield Sanitary Landfill, Staten Island, NY

Robinson and Handel (1995) conducted a study on the Brookfield Sanitary Landfill in the fall of 1992 to determine if woody plants could maintain growth in 1 foot or less vegetative soil cover over a 1.5-foot thick barrier clay. Nineteen species of woody plants were identified on the closed landfill; thirteen species had large individuals growing on the landfill. Volunteer species growing on the landfill ranged from 3 to 19.5-feet tall, with a maximum growth period of seven years. Test species that are native to Illinois included the grey birch (*Betula populifolia*), sweet gum (*Liquidambar styraciflua*), mulberry (*Morus* sp.), black cherry (*Prunus serotina*), pin oak (*Quercus palustris*), and black locust (*Robinia pseudoacacia*).

The root systems of thirty trees, and the underlying impacts to the clay barrier, were examined during the study. In all thirty specimens, shallow root systems were observed. Although the trees

studied had a wide variety of potential root growth forms, all roots were found growing above the clay layer. Taproots of various sizes were found deformed, and growing entirely above and parallel to the clay barrier. As well, the root systems for black cherry and pin oak, which reportedly can produce taproots that extend to depths greater than 3 feet, had no significant penetration into the clay barrier. The maximum root depth was equivalent to the depth of vegetative soil cover overlaying the clay barrier. For trees as tall as 20 feet, the overall root mass spread laterally rather than downward. The tree growth rate was not adversely impacted due to the shallow vegetative soil cover, with many trees being of average height and with sizable lateral root systems.

Case Study 3: Fresh Kills Sanitary Landfill, Staten Island, NY

Handel *et al* (1997) conducted a study in 1992 and 1993 on a closed portion of the Fresh Kills Sanitary Landfill, one of the largest municipal facilities ever constructed. Municipal waste was covered by an 18-inch thick clay cap, followed by 2 feet of vegetative soil. Seventeen species of native trees (ranging from 5 to 7.5-feet tall) and shrubs (ranging from 2 to 3.2-feet tall) were planted and studied for root growth dynamics. Approximately 550 individuals were planted at 5-meter intervals in a 15-row grid across the study area. The planted trees that are native to Illinois included red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), eastern red cedar (*Juniperus virginiana*), pitch pine (*Pinus rigida*), eastern white pine (*Pinus strobus*), American sycamore (*Platanus occidentalis*), black cherry (*Prunus serotina*), pin oak (*Quercus palustris*), and chestnut oak (*Quercus prinus*). In addition, the same species were planted on an adjacent earth berm to serve as a control group.

Specimen excavation was performed on both the landfill trees and control group to compare root architecture and growth depth. Observations showed that the rooting depths of the landfill trees were significantly less than the control group planted in identical subsurface soil. Additionally, in over three years of growth, no damage to the clay cap was observed, even as the depth of cover soil above the landfill cap ranged from 12 to 39-inches. It is important to note that many of the trees planted during the study had the capability of extending vertical roots below the depth of the overburden placed over the clay cap (as reported in Stone and Kalisz, 1991). In addition, no significant difference was observed in lateral fine root depth based on slope position or depth to the capping clay.

The authors state that species-specific differences in root morphology may not provide an adequate basis for selecting appropriate tree species to be planted above a clay barrier. Genetics, in combination with environmental factors, including soil mechanical resistance, moisture, aeration, pH, and environmental or abiotic factors, help dictate root spread, density, orientation, and depth. Additionally, the authors state that root growth is plastic and distinctions between root forms blur with respect to engineered soils. After the early stages of seedling development, tree and shrub roots will respond to the spatial and temporal variability between favorable and unfavorable soil conditions rather than grow blind to present environmental conditions.

### **3.5 SUMMARY**

The case histories and literature review indicate that trees on landfills, regardless of tree species and the thickness of the vegetative soil cover, develop shallow, lateral root systems that do not penetrate an underlying compacted clay cap. The factors limiting root depth are oxygen content, and the compaction of the soil beneath the roots. The case studies suggest that a minimum of one foot to two feet of vegetative soil cover over a clay cap is sufficient to safely sustain trees on a landfill.

## **4.0 ROOT PENETRATION STUDY AT BLACKWELL FOREST PRESERVE**

A root penetration study was conducted at the Blackwell Landfill to demonstrate, in conjunction with the literature research, that the root systems of trees and woody shrubs would not penetrate the clay cap given sufficient soil cover. The root penetration study was conducted in three phases. The first phase of the study was to identify the existing characteristics of the clay cap (Section 4.1), and the amount of existing vegetative soil cover present on the landfill (Section 4.2). The second phase consisted of a site reconnaissance specifically focusing on those areas of Blackwell that were considered to have suitable vegetative cover (Section 4.3). The third phase was a field study to determine if tree roots in the areas of suitable vegetative cover compromised clay cap integrity (Section 4.4).

### **4.1 EXISTING CLAY CAP**

The compaction and permeability of the soil determine the availability of the oxygen to the root surface, and the physical ability of roots to grow. As discussed in Section 3.1.2, tree roots will not penetrate tight, highly compacted soil because of physical impedance and reduced pore volumes that limit oxygen diffusion. Tree roots will not grow if they cannot exert enough pressure to push through the soil. As stated in Section 3.1.2, root studies conducted by Heilman (1981) indicate that total and vertical penetration of primary tree roots (Douglas-fir seedlings) decreased linearly with bulk densities in the range of 85.3 lb/ft<sup>3</sup> through 110.3 lb/ft<sup>3</sup>, while growth was restricted with soil bulk densities ranging from 109.0 lb/ft<sup>3</sup> through 114.0 lb/ft<sup>3</sup>.

The bulk density of the clay cap at the Blackwell Landfill has been tested during the course of the recent remedial actions at the site (Figure 5). A cap delineation study indicated that the dry bulk density of the original clay cap varies from about 105.4 lb/ft<sup>3</sup> to 130.3 lb/ft<sup>3</sup>, with an average density of 118.4 lb/ft<sup>3</sup> (Montgomery Watson, 1997). As well, quality assurance testing conducted during construction of the cap repairs in 1997 and 1998 indicated that the dry bulk density of the repaired cap varied from about 101.1 lb/ft<sup>3</sup> to 119.9 lb/ft<sup>3</sup>, with an average density of 113.1 lb/ft<sup>3</sup> (Montgomery Watson, 1999). These values are consistent with soil environments identified by Heilman (1981) at which tree root growth would be reduced or severely restricted. Therefore, tree roots are not expected to penetrate the clay cap on the Blackwell Landfill.

### **4.2 EXISTING VEGETATIVE SOIL COVER**

The distribution and thickness of the vegetative soil cover over the compacted clay cap on the Blackwell Landfill was mapped using soil boring data compiled during the following previous investigations:

- Blackwell Forest Preserve Deep Vents and Exploratory Borings (Testing Service Corporation, 1986);
- Technical Memorandum Predesign Investigation (Montgomery Watson, 1997); and
- Revised Predesign Report (Montgomery Watson, 1997).

The data indicates that the thickness of vegetative soil cover on parts of the Blackwell Landfill vary from less than six inches (i.e., topsoil) to greater than twelve feet. However, there are only four definable areas on the landfill that have vegetative soil cover greater than one foot thick (Figure 6). A map providing test boring details is provided in Appendix B. On the rest of the landfill, either the vegetative soil cover is less than one foot thick, or the lateral extent of the vegetative soil cover greater than one foot could not be defined.

### 4.3 SITE RECONNAISSANCE

A site reconnaissance was conducted at the Blackwell Landfill to identify the number and types of woody species within the defined areas of vegetative soil cover (Figure 6), and to identify the dominant vegetation over the remainder of the landfill. Montgomery Watson and CDF conducted the reconnaissance on October 28, 1998.

The site reconnaissance indicated that, in general, most plant species on the landfill appeared healthy, with the majority of the landfill covered by various non-native grass species, such as *Bromus inermis* (Hungarian brome) and *Poa pratensis* (Kentucky blue grass). *Coronilla varia* (crown vetch) was also noted on several parts of the landfill. Crown vetch is a shallow-rooted perennial forb that was previously considered choice vegetation for landfills to prevent erosion. However, recent experience shows that crown vetch has shallow and weak roots, and is less able to prevent soil erosion compared to native prairie species.

The site reconnaissance also indicated that native and non-native tree species are currently present on several areas of the landfill, although few trees were noted on the landfill's southern side, possibly due to steeper slopes. Sixteen species of woody plants were observed growing within three of the four areas with 1 foot or greater of vegetative cover soil. The fourth area was void of trees or woody shrubs. A complete list of woody species and the dominant herbaceous species identified in the four defined areas is provided in Appendix A. The tree species growing outside the four areas of vegetative soil cover were not fully cataloged.

The site reconnaissance identified a number of non-native tree species that are considered invasive and competitive with native flora (such as oaks), including *Rhamnus cathartica* (common buckthorn) and *Elaeagnus umbellata* (autumn olive), both located in Areas 1, 2 and 4. These competitive non-native species can be detrimental to a landfill cap. For instance, buckthorns have very dense leaf canopies that shade the ground. Bottom layer plants that require some sunlight, such as the brome grass found at the Blackwell Landfill, are unable to maintain growth beneath the buckthorns and die. With the bottom layer plants gone, the soil becomes high susceptible to erosion. The field reconnaissance observed a couple of areas where there was no vegetation growth beneath the buckthorns.

As well, the field reconnaissance identified other trees that were overgrown, or were in poor health due to naturally-occurring tree diseases not attributable to the landfill. These species included *Populus nigra italica* (Lombardy poplar) which are cankerous as stated in Section 1.2,

and *Populus alba* (white poplar). Other species, such as a grove of *Malus coronaria* (crab apple), appear to have been planted in their present locations along a landfill access road.

The site reconnaissance did not reveal any evidence of windthrow.

#### 4.4 FIELD STUDY

Montgomery Watson and CDF conducted the root penetration study on December 9, 1998. The study was originally intended to focus on trees selected from areas of vegetative soil cover that were greater than 2 feet thick. However, suitable trees for the study (see below) were identified in only one of the four areas. Therefore, the study was expanded to nearby unmapped areas that also had suitable trees.

The root penetration study was conducted on five trees at the locations shown on Figure 6. These five trees were selected based upon:

- Generally being native to DuPage County;
- Having acceptable aesthetic qualities;
- Having a variety of different rooting systems; and
- Appearing healthy.

The specific species chosen for the study were an eastern red cedar (*Juniperus virginiana crebra*), slippery elm (*Omus pumila*), smooth sumac (*Rhus glabra*), silver maple (*Acer saccharinum*), and a honey locust (*Gleditsia triacanthos*).

The root penetration study consisted of excavating the tree, exposing the root system by tipping the tree on the ground, and examining the root systems of each tree. The root configuration, soil types and thickness, approximate height of the tree and the DBH were noted. As noted previously, the DBH is defined as the tree diameter at 4.5 feet above ground surface. Cross-sections summarizing the information obtained are shown in Figures 7 through 11. Select information is also tabulated in Table 1.

##### **Eastern Red Cedar (Area 4, Unit 8):**

The Eastern Red Cedar was located in Area 4 on the west-side of the landfill (Figure 6). The area was generally flat, and was mostly covered by brome grass. The red cedar was located approximately 50 feet southeast of leachate extraction well EW08. The cedar is a type of conifer that typically has a shallow root system. This cedar was approximately 10.5 feet tall and 2 inches DBH. The tree appeared to be healthy.

Soil was excavated next to the tree to a depth of 2.8 feet below ground surface (bgs) prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 7. The cedar's root system consisted of shallow woody roots that spread out laterally a distance almost equal to the canopy diameter of the tree. A taproot did not exist, and the deepest woody root observed penetrated 1.5 feet bgs, which corresponds to the top of a clayey gravel

layer. No root penetration into the compacted clay layer was evident, and there was no evidence of desiccation cracking of the clay below the tree roots.

A total of 20 eastern red cedars are present in three of 14 units on the landfill. The largest individual found on the landfill was 3" DBH and 10 feet tall. The cedar that was excavated during the root penetration field was of comparable height to the largest cedar on the landfill. [Note: The cedar was not documented in Unit 8 during the 1999 field reconnaissance because the tree was not replanted following excavation.]

**Slippery Elm (Area 4, Unit 8):**

The slippery elm was located near the perimeter of Area 4, approximately 75 feet east of leachate extraction well EW08 (Figure 6). The elm stood in a stand of diseased poplar trees, although the elm appeared to be healthy. The elm was approximately 10.5 feet tall and 2.5 inches DBH.

Soil was excavated next to the tree to a depth of 2.4 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 8. The elm exhibited long horizontal roots with a maximum root penetration depth of approximately 1.6 feet bgs, with a nominal penetration by a small "feeder root" of approximately 0.1-foot into the underlying compacted clay layer. A taproot did not exist, and there was no evidence of desiccation cracking of the clay below the tree roots.

The slippery elm was the only individual of its species growing on the landfill, and was the only elm identified in both the 1998 and 1999 field reconnaissance studies.

**Smooth Sumac (outside of Area 3, inside Unit 11):**

The smooth sumac was located on the southern slope of the landfill (Figure 6) in an area covered by a combination of brome grass and crown vetch. The sumac was located approximately 250 feet east of vent SV12. The selected sumac was positioned near the center of a colony of sumacs (i.e., sumacs propagate by cloning). The sumac was approximately 10.8 feet tall with a DBH of 2.5 inches.

Soil was excavated next to the tree to a depth of approximately 2.0 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 9. A taproot was not evident, and there was no evidence of desiccation cracking of the clay below the tree roots. The maximum root penetration depth of 1.3 feet bgs, which corresponds to the top of the clay fill layer (i.e., the roots did not penetrate the compacted clay layer).

The average DBH and height of the sumacs in this thicket are 1 inch and 8 feet tall, respectively. The smooth sumac chosen for the root penetration field study was 2.5" DBH and 10.8 feet tall, which makes the excavated sumac larger than average.

#### **Silver Maple** (outside of Area 3, inside Unit 6):

The silver maple was also located on the south side of the landfill to the west (Figure 6), and adjacent to, the sumac colony. The silver maple is not a native species; however, it was one of the tallest trees currently on the landfill. The silver maple was 15 feet tall with a DBH of 4 inches.

Soil was excavated next to the tree to a depth of approximately 4.5 feet. The silver maple was not tipped. Details of the observed root system and soil types are presented in Table 1 and Figure 10. The underlying compacted clay layer was not encountered in the excavation; a deeper excavation was not possible due to the surrounding steep landfill slopes. Roots were observed to be growing to the maximum depth excavated, and a taproot was not identified. Desiccation cracking was not evident at the maximum depth of excavation.

The largest silver maple on Blackwell Landfill was estimated at 6" DBH with a height of 20 feet, which is comparable in size with the excavated silver maple. The silver maple was found in two units of the landfill, with a total count of 42 individuals (including saplings).

#### **Honey Locust** (outside of Area 3, inside Unit 6):

The honey locust is located on the south side of the landfill (Figure 6), in an area mostly covered with grasses and crown vetch. The honey locust was located approximately 100 ft south of landfill gas vent SV12 between two adjacent honey locust trees. The honey locust was approximately 10.5 feet tall with a DBH of 2 inches.

Soil was excavated next to the tree to a depth of approximately 2.8 feet bgs prior to tipping the tree. Details of the observed root system and soil types are presented in Table 1 and Figure 11. A taproot was not present, and all large roots were observed to be growing horizontally. Lateral roots were not observed below 0.9 feet bgs. The tree roots extended to a maximum depth of 2.3 feet bgs, which is within a wet, uncompacted clay layer. No root penetration into the compacted clay layer was evident and there was no evidence of desiccation cracking of the clay below the tree roots.

Sixty-seven honey locust trees were noted in three units during the 1999 field reconnaissance. The largest honey locust is located on a berm in the northern part of the landfill (Unit 2), and measures 8 inches DBH and 25 feet tall. The honey locust chosen for the root penetration study was positioned on the steeper southern slope of the landfill (Unit 6).

## **4.5 SUMMARY**

The environmental conditions on the Blackwell Landfill currently support a diversity of plant life on all sections of the landfill. The majority of the landfill is covered by various non-native grass species, such as *Bromus inermis* (Hungarian brome) and *Poa pratensis* (Kentucky blue grass), with *Coronilla varia* (crown vetch) also noted on several parts of the landfill. Sixteen species of

woody plants were noted in the four defined areas of adequate vegetative soil cover on the landfill.

A root penetration study was conducted on five trees located on the landfill. The tree roots were excavated, and the root configuration and soil types and thickness were noted. This study indicates that the tree roots spread laterally when they encountered an underlying soil barrier such as the clay cap, and would only continue to grow vertically if there was no underlying barrier. Desiccation cracking of the clay underneath the tree roots was not evident during the root penetration field study. Except for one minor instance where the total thickness of vegetative soil cover was only 1.5 feet thick, the tree roots did not penetrate the underlying compacted clay cap. Even in this instance, one tree root, identified as a feeder root and not a taproot, only penetrated approximately 0.1 feet into the compacted clay. This penetration of the feeder root is not considered significant.

## **5.0 FACTORS AFFECTING TREE GROWTH ON LANDFILLS**

By its nature, a landfill may not provide the most hospitable environment for long-term, sustainable growth. Therefore, numerous conditions must be considered when establishing a tree management plan for a landfill. This includes soil conditions (e.g. soil aeration, permeability, fertility and moisture), external factors that are somewhat unique to landfills (e.g. landfill gas and leachate production), location on the landfill, and care and maintenance. The following sections provide general information regarding these factors, and how they relate to the Blackwell Landfill.

### **5.1 SOIL CONDITIONS**

#### **5.1.1 Aeration**

Soil aeration is necessary for a tree's survival, and is a governing factor that controls the depth of root growth. Oxygen is required for respiration, and a reduced oxygen supply will almost instantaneously halt root growth. While the minimum concentration of oxygen required for root growth has not been clearly defined, as reported in Dobson and Moffat (1993), studies by Kozlowski reported the when soil oxygen content drops below 10%, root growth is greatly restricted and at approximately 3% - 5%, root growth ceases.

The current oxygen levels in the vegetative soil cover at the Blackwell Landfill are not known. However, even without the benefit of a quantitative study, several qualitative observations can be made at about the oxygen levels at the site. The Blackwell Landfill has well-established vegetation, as described in Section 1.2, as well as several areas with shrubs and trees. The vegetation is healthy and does not appear to be stressed. In addition, Blackwell has a two-foot thick clay cap over refuse, which acts as a barrier to oxygen depletion in the root zone by preventing landfill gas migration. Therefore, the oxygen levels in the vegetative soil cover at the Blackwell Landfill are adequate to sustain vegetation.

#### **5.1.2 Soil Fertility**

Tree root growth and development are dependent on the available nutrients in the soil environment. The major nutrients for tree growth include magnesium, phosphorus, potassium, and calcium, while the minor nutrients include nitrogen compounds and the trace elements iron, manganese, zinc, copper, and boron (Flower *et al*, 1978). However, the concentrations of metals in the soil must have a delicate balance in order to foster tree growth, and soils with high concentrations of heavy metals should be avoided (Gilman *et al*, 1985).

Soil fertility does not appear to be a problem at the Blackwell Landfill. The number and variety of species growing on the landfill and their relatively healthy appearance support this conclusion. In addition, based on the root penetration study (Section 4.4), the examined root systems appeared healthy and well branched.

### 5.1.3 Soil Moisture Content

An excess or deficiency in soil moisture content can greatly affect the ability of a tree to grow. Excess soil moisture, or water logging, can lead to decay or death of the existing root system, while drought conditions can impede root growth or cause root damage.

Soil moisture content does not appear to be a concern at the Blackwell Landfill based on the number and variety of species currently being supported. The landfill's topography is suited to promote runoff. Moreover, during the root penetration study, water logging was not observed, as evidenced by the absence of decaying or dead roots and a stagnant water layer present above the compacted clay cap.

## 5.2 EXTERNAL CONDITIONS

### 5.2.1 High Temperatures

Elevated soil temperatures at closed sanitary landfill can damage trees by decreasing soil moisture and providing too warm of a soil environment in the root zone. However, higher soil temperatures may also extend the growing season, and could provide some protection from winter or spring frosts (Ruark *et al* 1982). Although the optimum root zone temperature varies with tree species, the average optimum root zone temperature is between 10 to 30 °C.

Elevated soil temperatures at the Blackwell Landfill do not appear to pose a problem. The landfill has well-established, healthy vegetation. The trees on the Landfill are estimated to be 10 to 15 years old, and they would not have survived if the temperature levels in the soils were too high.

### 5.2.2 Leachate

Leachate is the term for the resultant liquid that is generated in a landfill as water infiltrates through the waste. Leachate can have a chemical makeup that is toxic and harmful to vegetation, although at some landfills captured leachate has been irrigated into plots of trees as a means for leachate disposal (Dobson and Moffat, 1993). Damage to vegetation usually occurs only at the landfill surface where a leachate seep is occurring. Typically, leachate seeps occur on the edges of landfill or in low-lying areas where there is little or no cap.

Damage to vegetation from exposure to leachate is not occurring at the Blackwell Landfill, and is not expected to occur in the future. There are no known leachate seeps, and all vegetation appears to be healthy except for known tree diseases (non-landfill related). As well, the leachate at the Blackwell Landfill is controlled through a leachate collection system installed in 1997.

### 5.2.3 Landfill Gas

Landfill gas is a complex composite of gas generated during the decomposition of biodegradable waste contained within the landfill. Typically, gas production peaks in a number of years following landfill closure, and then falls off over time. Methane and carbon dioxide typically comprises the largest volume of the gas. This gas can migrate from the landfill and diffuse through the compacted cap to the root zone. Harmful effects from landfill gas are caused by the

gas displacing oxygen and elevating carbon dioxide levels. Elevated levels of carbon dioxide have been shown to be toxic to tree roots (Dobson and Moffat, 1993).

Historically, landfill gas accumulation at the Blackwell Landfill has been controlled by a series of individual passive vents. This system was augmented in 1997 by an engineered gas extraction system. However, historical evidence suggests that gas production at the landfill has been declining over the past ten years. There is no evidence of landfill gas causing damage to vegetation at the Blackwell Landfill. All vegetation appears to be healthy except for known tree diseases.

## 5.3 LOCATION

### 5.3.1 Slope And Sun Exposure

The slope of the land and the weather exposure will effect the success of tree growth on the landfill. Certain trees may not fair well on parts of Mount Hoy that have very steep slopes. The success of any woodland cover will require that slope and weather exposure be evaluated with respect to the species of trees planted and maintenance requirements. As well, if mechanical devices are used to plant trees, the maximum safe slope for the equipment is three horizontal to one vertical.

### 5.3.2 Location of Control Structures

The Blackwell Landfill's leachate collection system (LCS) currently consists of nine extraction wells and two lift stations that are located at the north and south areas of the landfill. Twelve shallow and sixteen deep gas vents are also located throughout the landfill. Four manholes help direct storm water to the lift stations. An access road to the top of Mount Hoy is present in the southern half of the landfill. Tree restoration in these areas must be designed and implemented as not to interfere with these features because they are imperative to the daily operation and maintenance of the landfill. In addition, intrusive activities near any LCS components will not be allowed as it may cause damage to the buried piping. Trees must not be planted over the LCS conveyance piping.

### 5.3.3 Natural Habitat Area

The Blackwell Landfill is located immediately north of the Blackwell Kame<sup>1</sup> (Figure 2). This eight-acre area is the only kame in DuPage County that still contains a high-quality remnant prairie and woodland. The FPD has been managing the Kame last 20 years with regular, controlled burns, and in recent years there has been some restoration activity in the ambient woodlands.

The Blackwell Kame is the only known location in the county for rare species such as *Arenaria stricta* (stiff sandwort) and *Carex umbellata* (early oak sedge). Other rare species include

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<sup>1</sup> A kame is a low, steep, rounded hill or ridge of layered sand and gravel drift, developed from glacial deposits. Kames were probably formed by streams of melting glacial ice that deposited mud and sand along the ice front. The subsequent retreat of the glacier left them as more or less isolated hills and ridges, ranging in height from a few feet to 100 feet (30 m) or more.

*Asclepias viridiflora* (short green milkweed), *Brachyelytrum erectum* (Long-awned wood grass), *Bromus latiglumis* (eared-leaved brome), *Carex meadii* (Mead's stiff sedge), *Echinacea pallida* (purple coneflower), *Eryngium yuccifolium* (rattlesnake master), *Helianthus occidentalis* (western sunflower), *Hypoxis hirsuta* (yellow star grass), *Lathyrus venosus* (veiny pea), *Liatris cylindracea* (cylindrical blazing star), *Lithospermum latifolium* (broad-leaved pucoon), *Panicum leibergii* (prairie panic grass), *Scutellaria parvula* v. *leonardi* (small skullcap), *Silene virginica* (fire pink), and *Viola pedatifida* (prairie violet). One of the largest known white oaks in DuPage County is situated along the western edge of the kame.

The Blackwell Kame is considered a highly valued nature habitat within DuPage County, and the Blackwell Landfill is located in its buffer zone. Managing the non-native, "undesirable" species on the landfill, such as Eurasian weeds and trees, will minimize the infiltration of these species into the Blackwell Kame through wind and animal dispersion.

## 5.4 CARE AND MAINTENANCE

Care and maintenance is an important factor in the successful growth of trees on landfills. As reported in Dobson and Moffat (1993), Barbour conducted a survey of waste regulation authorities in 1989 in Great Britain, which concluded that the success of tree planting on landfill sites had less to do with the site and tree species characteristics than the degree of maintenance and the selection of suitable planting stock. In turn, Dobson and Moffat (1993) indicated that poor silvicultural practices, such as the use of unqualified and untrained personnel, inappropriate planting stock, and ineffective weed control, resulted in poor success of establishing trees on landfills.

Other factors to be considered when developing trees on landfills include irrigation, fertilization, weed maintenance, and protection from vandalism and animals (e.g. tree shelters, vinyl tree guards, or tree wrap).

## **6.0 WOODY VEGETATION COVER OPTIONS**

### **6.1 INTRODUCTION**

The Blackwell Landfill will support a diversity of grass and tree species, and there are no unique combinations of vegetation that would be considered most suitable for the site. Most species of grasses and trees are considered appropriate. However, trees and woody shrubs are only appropriate on those parts of the landfill where there is at least two feet of vegetative soil cover over the clay cap.

The vegetation options described below provide for flexibility in the plant ecosystem that can be developed on the Blackwell Landfill. The options allow for predominantly grass species over the entire landfill, or for woody vegetation on those portions of the landfill that have sufficient thickness of vegetative cover soil. In addition, the options allow for the plant ecosystem to be modified over time, depending upon the long-term development needs of the FPD.

### **6.2 RECOMMENDED VEGETATIVE SOIL COVER THICKNESS**

The vegetative soil cover must be sufficiently thick to accommodate the anticipated root volume and support the tree roots. The case study by Robinson and Handel (1995) (see Case Study No. 2, Section 3.4) demonstrated that one foot of vegetative soil cover was sufficient to support healthy and sustainable growth for several tree species. As well, the root penetration study at the Blackwell Landfill (Section 4.0) indicated that tree roots of healthy were growing in as shallow as 1.3 feet of available vegetative soil cover. However, Gilman *et al* (1981b, 1985) recommends that at least two feet of vegetative soil cover be provided to support tree growth. Therefore, we recommend that at least two feet of vegetative soil cover be provided over the clay cap at the Blackwell Landfill in those areas that are intended to support tree growth. The current locations with known thickness of vegetative soil cover greater than two feet are shown on Figure 6.

If additional vegetative soil cover is required, standard arboreal practice requires that it be permeable to air and water. As well, standard practice suggests that the soils should be placed when dry, and compaction should be avoided. Organic amendments (such as humus, peat moss, manure, crop residues, composted sewage sludge, or refuse compost) will improve the physical, chemical, and biological properties of most cover soil by reducing soil density. As well, the top 4 to 6 inches of the soil cover should consist of topsoil because this is where most of the feeder roots will grow.

### **6.3 WOODY VEGETATION COVER OPTIONS**

The literature review and root penetration study presented earlier in this report indicate that trees are being, and can continue to be, successfully grown on the Blackwell Landfill without compromising the underlying clay cap. However, development of a healthy, self-sustaining ecosystem requires planning, maintenance, and financial commitment. Therefore, general cover

options have been developed which allow the FPD to select the type of plant ecosystem that would be most appropriate for the public's use of the Blackwell Forest Preserve.

The general cover options for the woody plant ecosystems consist of:

- Option 1: Removal of all trees from the landfill;
- Option 2: Removal of unsuitable trees; and
- Option 3: Addition of woody vegetation.

In combination with these woodland options, the cover options for the grass ecosystem consist of Native Prairie or Eurasian Meadow grass species.

#### **6.3.1 Woody Vegetation Option 1: Remove all Trees from the Landfill**

This is an aggressive option that removes all trees and shrubs from the landfill. Any concerns regarding woody vegetation would be thereby eliminated. Disturbed areas would be repaired with suitable grasses.

#### **6.3.2 Woody Vegetation Option 2: Remove Unsuitable Trees**

For this option, all woody vegetation outside of the four defined areas of vegetative soil cover (Figure 6) would be removed from the landfill. Disturbed areas would be repaired with suitable grasses. As well, unsuitable woody vegetation located within the four defined areas of vegetative soil cover would be removed. Unsuitable woody vegetation consists of those that have an invasive nature, competitive with native flora, or are in poor health. Examples of unsuitable trees include *Populus alba* (white poplar), *Elaeagnus umbellata* (autumn olive), *Populus nigra italica* (Lombardy poplar) which is diseased and cankerous (as discussed in Section 4.3), and *Rhamnus cathartica* (common buckthorn) which is invasive. It should be noted that selection of Woody Vegetation Option 2 would result in nearly all trees and shrubs being removed from the landfill.

#### **6.3.3 Woody Vegetation Option 3: Addition of Native Trees**

Option 3 is a variation of Option 2 that would include removal of unsuitable woody vegetation from the four defined areas of vegetative soil cover, and the removal of all woody vegetation from the remaining areas of the landfill. However, the FPD would have the option of expanding the woody vegetation by planting additional trees and shrubs in the four defined areas of vegetative soil cover, or by planting trees and shrubs in new areas of vegetative soil cover at least two feet thick.

This option could also involve removing non-native trees and shrubs from the four defined areas of vegetative soil cover, and planting additional native species.

From an ecological perspective, Wood Option 3 is attractive considering the close proximity of the landfill to the Blackwell Kame, and the current FPD efforts to restore and maintain this Kame.

## 6.4 SUITABLE GRASS SPECIES

Most grass species that are sufficiently hardy for the DuPage County are acceptable for growing on the Blackwell Landfill. However, the grass species must be selected by ecologists familiar with growing conditions on the Landfill.

The recommended grasses for the Blackwell Landfill are Native Prairie species. A Native Prairie would consist of native grasses and wildflowers. This type of ecosystem is naturally stable and self-sustaining. Native plants are supremely suited for the local climatic conditions, and there are a wide variety of species to choose from, which can result in a very diverse system. Native plant communities are often more attractive to a wider variety of mammals, birds and insects (many of which can be rare). The public often finds the Native Prairie ecosystem more interesting due to its diversity. A Native Prairie also resists invasion of derelict grass species if the native system is vast. Prairie grasses ultimately should provide the fuel matrix for maintaining a woody plant or prairie system, but for a greater diversity of species, the native system should contain perennial wildflowers.

The roots of native prairie grasses can grow up to several meters deep in their native soils (Robinson and Handel, 1995). Unfortunately, the environmental conditions (i.e., the soil matrix) under which this root growth occurred was not described. However, as with tree roots, grass roots are expected to grow horizontally in the presence of an underlying confining layer such as a compacted clay cap. To confirm that vertical growth of grass roots is impeded by the compacted clay layer, a long term monitoring program, as described in Section 7.3.4, is recommended.

A Eurasian Meadow is the typical plant community that is established on landfills today and is the current vegetation at the site. It would be a suitable alternative to native prairie grasses and wildflowers. However, the Eurasian Meadow consists of perennial grasses that are not native to the region. It is a low-diversity system, dominated by perennial Eurasian grasses, and is attractive to only few animal species. If a few Eurasian perennial clovers and wildflowers are included in the mix, it can be a fairly attractive landscape for two to three months per year. Care must be taken when considering a Eurasian plant community because it could be a threat to the integrity of the nearby Blackwell Kame. Examples of suitable Native Prairie and Eurasian Meadow grasses and wildflowers are listed below.

<b>Dominant Prairie Grasses</b>	
<i>Andropogon gerardii</i>	Big Bluestem
<i>Andropogon scoparius</i>	Little Bluestem
<i>Elymus villosus</i>	Hairy Wildrye
<i>Panicum virgatum</i>	Switchgrass
<i>Sorghastrum nutans</i>	Yellow Indiangrass
<i>Sporobolus heterolepis</i>	Prairie Dropseed

<b>Perennial Prairie Wildflowers</b>	
<i>Asclepias tuberosa</i>	Butterfly Milkweed
<i>Asclepias verticillata</i>	Whorled Milkweed
<i>Aster ericoides</i>	Heath Aster
<i>Aster azureus</i>	Skyblue Aster
<i>Aster laevis</i>	Smooth Aster
<i>Aster novae-angliae</i>	New England Aster
<i>Carex bicknellii</i>	Bicknell's Sedge
<i>Carex brevior</i>	Fescue Sedge
<i>Carex molesta</i>	Troublesome Sedge
<i>Coreopsis palmata</i>	Stiff Tickseed
<i>Coreopsis tripteris</i>	Tall Tickseed
<i>Dodecanteon meadia</i>	Pride of Ohio
<i>Eryngium yuccifolium</i>	Button Eryngo
<i>Euphorbia corollata</i>	Flowering Spurge
<i>Galium boreale</i>	Northern Bedstraw
<i>Gentian flavida</i>	Plain Gentian
<i>Gentiana puberulenta</i>	Downy Gentian
<i>Helianthus mollis</i>	Ashy Sunflower
<i>Helianthus rigidus</i>	Rigid Sunflower
<i>Heliopsis helianthoides</i>	Sunflower Heliosis
<i>Heuchera richardsonii</i>	Richardson's Alumroot
<i>Lespedeza capitata</i>	Roundhead Lespedeza
<i>Liatris aspera</i>	Tall Gayfeather
<i>Liatris pycnostachya</i>	Cattail Gayfeather
<i>Liatris spicata</i>	Dense Gayfeather
<i>Parthenium integrifolium</i>	Wild Quinine
<i>Petalostemum candidum</i>	White Prairie Clover
<i>Petalostemum purpureum</i>	Purple Prairie Clover
<i>Phlox pilosa</i> v. <i>fulgida</i>	Downy Phlox
<i>Rosa carolina</i>	Carolina Rose
<i>Rudbeckia hirta</i>	Blackeyed Susan
<i>Rudbeckia subtomentosa</i>	Sweet Cornflower
<i>Siphium integrifolium</i> v. <i>deamii</i>	Wholeleaf Rosinweed
<i>Silphium laciniatum</i>	Compass Plant
<i>Silphium terebinthinaceum</i>	Prairie Rosinweed
<i>Smilacina stellata</i>	Starry False Solomon's Seal
<i>Solidago juncea</i>	Early Goldenrod
<i>Solidago nemoralis</i>	Dyersweed Goldenrod
<i>Solidago rigida</i>	Stiff Goldenrod
<i>Tradescantia ohimensis</i>	Bluejacket
<i>Viola pedatifida</i>	Prairie Violet
<i>Zizia aurea</i>	Golden Zizia

<b>Perennial Eurasian Grasses</b>	
<i>Agrostis alba</i>	Red Top
<i>Bromus inermis</i>	Hungarian Brome
<i>Dactylis glomerata</i>	Orchard Grass
<i>Festuca elatior</i>	Tall Fescue
<i>Festuca rubra</i>	Red Fescue
<i>Phleum pratense</i>	Timothy
<i>Poa compressa</i>	Canada Bluegrass
<i>Poa pratensis</i>	Kentucky Bluegrass
<b>Perennial Eurasian Wildflowers</b>	
<i>Chrysanthemum leucanthemum</i> var. <i>pinnatifidum</i>	Oxeyedaisy
<i>Coreopsis lanceolata</i>	Lanceleaf Tickseed
<i>Trifolium hybridum</i>	Alsike Clover
<i>Trifolium pratense</i>	Red Clover

## 6.5 SUITABLE TREE SPECIES

Most tree and shrub species that are sufficiently hardy for the DuPage County are acceptable for growing on the Blackwell Landfill. However, the exact species of trees and shrubs that will be grown on the landfill must be selected by ecologists familiar with growing conditions on the landfill. The main criteria when selecting trees and shrubs are that the species must be compatible with its general location on the landfill, and must be compatible with surrounding tree and grass species. General protocols for selection of tree and shrub species is provided in Section 7.0 of this report. The few tree species that are not considered acceptable are those species that are aggressively invasive and competitive, and those species whose canopy blocks sunlight to the growing bottom layer of plants. Examples of these unsuitable tree species include common buckthorn and autumn olive.

Suitable trees for the Blackwell Landfill can be either native or non-native species. However, native species attract more animal species, particular birds for perching and nest building activities, and therefore are recommended. In turn, birds feeding patterns increase the potential for seed dispersal, which is an important mechanism in maintaining woodlands and increasing plant density. Native trees that commonly grow in DuPage County include oaks, hickories, and walnuts. Non-native trees, while still being suitable, can become derelict. Without proper maintenance, non-native trees can increase the potential for cover erosion if undergrowth is allowed to disappear.

Examples of the more common tree species native to DuPage County are provided below.

<b>Suitable Native Trees</b>	
<i>Carya cordiformis</i>	Bitternut Hickory
<i>Carya ovata</i>	Shagbark Hickory
<i>Corylus americana</i>	American Hazelnut
<i>Fraxinus americana</i>	White Ash
<i>Juglans nigra</i>	Black Walnut
<i>Ostrya virginiana</i>	Eastern Hophornbeam
<i>Prunus serotina</i>	Black Cherry
<i>Quercus alba</i>	White Oak
<i>Quercus macrocarpa</i>	Bur Oak
<i>Quercus rubra</i>	Northern Red Oak
<i>Quercus velutina</i>	Black Oak
<i>Quercus coccinea</i>	Scarlet Oak
<i>Viburnum prunifolium</i>	Blackhaw
<i>Tilia americana</i>	American Basswood
<i>Pinus resinosa</i>	Red Pine
<i>Pinus strobus</i>	Eastern White Pine

## **7.0 PROTOCOLS FOR WOODY VEGETATION EXPANSION**

### **7.1 SUITABLE WOODY VEGETATION GROWTH AREAS**

The areas on the landfill that are currently suitable for expansion of woody plants are shown on Figure 6. This figure identifies the four defined areas with at least a two-foot thickness of vegetative soil cover, and existing control structures. However, following completion of cap repairs 1998, the FPD placed considerable thickness of topsoil on parts of the landfill to improve overall site drainage. These areas of new topsoil, if greater than two feet in thickness, will be suitable for establishing additional woody plants. If the FPD chooses to establish woody plants in these areas, the areas must be mapped and the total thickness of soil cover must be established. If the FPD desires to establish woody plants on other parts of the landfill that do not currently have defined soil cover, a minimum of two feet of new vegetative soil cover must be placed in those areas. Suitable new vegetative soil cover consists of uncompacted sandy or silty soils that are covered with a minimum of six inches of topsoil.

### **7.2 DEED RESTRICTIONS**

In 1997 and in accordance with the Unilateral Administrative Order (UAO), the FPD placed a deed restriction on the Blackwell Landfill. This deed restriction bars future development and groundwater use within the landfill boundaries. A copy of the deed restriction is provided in Appendix C. Specifically, the deed restriction states that:

- There shall be no use of, or activity, on the site that may interfere with, damage, or otherwise impair the effectiveness of completed response action, except with written approval of the U.S. EPA.
- There shall be no use of groundwater underlying the site, except with written approval of the U.S. EPA.
- There shall be no residential, commercial or agricultural use of the landfill, including excavation, landfilling, mining, invasive construction and drilling, except with written approval of the U.S. EPA.
- There shall be no tampering or removal of containment or monitoring systems.
- There shall be no activities that cause destruction of vegetation on the landfill that could cause degradation of remedial components.
- There shall be no ignition sources on the landfill, except with written approval of the U.S. EPA.

The restoration plans developed for the Blackwell Landfill, as well as necessary care and maintenance, must comply with all terms of the deed restriction.

## **7.3 RESTORATION STRATEGY**

A restoration strategy will be prepared upon the FPD's selection of the woody vegetation and grassland options for the Blackwell Landfill, and prior to any revegetation efforts. This strategy will be summarized in a follow up report entitled "Comprehensive Restoration Strategy for the Revegetation of Blackwell Landfill". The report will describe the locations where grass and woody vegetation will be developed on the Landfill, as well as specific grass, shrub and tree species. The report will also describe the planting strategy, field verification of the available vegetative layer; woody vegetation implementation; and long-term monitoring. A general description of each component is briefly discussed below:

### **7.3.1 Planting Strategy:**

A planting strategy will be developed to select areas on the Landfill for the planting of grasses or woody vegetation. This strategy will consider:

- The end use scenario;
- Potential windthrow conditions;
- Access to LCS control structures and equipment (vaults, monitoring wells, gas vents, buried leachate or landfill gas conveyance pipes, control buildings and security fences);
- Extreme environmental conditions such as steep slopes; and
- Silvicultural issues including planting techniques, tree spacing, and height and age of trees to be planted.

Plants will be selected with consideration of the following:

- Differences in slope of the landfill and sun exposures;
- The unsuitability of certain trees, shrubs and grasses;
- The rate of tree growth (i.e., slower growing trees have been shown to be more tolerant to landfill conditions than certain rapidly growing species);
- The influence of mycorrhizal fungi; and
- Additional considerations, including mulch, soil amendments, and establishment of the community underneath the canopy of the tree.

In addition, the wetness and the conservatism categories (as described in Section 1.2) will be used to aid in the selection of plant species. The wetness categories will allow selection of species that will thrive in the well-drained conditions on the landfill. The conservatism categories will allow species that are sufficiently tolerant of disturbed soil conditions. Conservatism coefficients between 3 and 6 are considered most suited to the Landfill. Tree species with conservatism coefficients from 7 to 10 are unlikely to survive on the landfill, while species with conservatism coefficients below 2 are inappropriate in that they volunteer over time with the potential to expand coverage to undesired areas.

The planting strategy will also consider the use of controlled burns to control the growth of unsuitable grasses and woody vegetation. Since 1975, controlled burns have been a management technique in place at many forest preserves in the FPD's holdings, as well as other Forest Preserve Districts in Illinois. This is also consistent with management practices at other landfills. For example, prairie burns are routinely conducted at Settler's Hill Landfill located in Batavia, Illinois in Kane County.

Only qualified personnel (trained to meet National Wildfire Coordinating and Group standards) can undertake prescribed burnings. All control structures on and surrounding the landfill must be protected during the burns. Currently, all controlled burns performed by FPD are conducted under IEPA and local fire department permit. Coordination between the DuPage County Health Department, local police, DuPage County Sheriff, and local and adjacent fire department is also maintained during the burn.

Controlled burns of native grasses are typically easier than mowing and native grasses respond better if they are burned on a regular basis. However, because methane is passively vented at Blackwell Landfill through a series of shallow and deep landfill gas vents, the feasibility of conducting prairie burns on the landfill must be thoroughly considered prior to establishing vegetation requiring controlled burns. The following will be considered by qualified prairie burn personnel to determine the feasibility of conducting controlled burns at Blackwell Landfill:

- Shape of landfill;
- Amount of moisture in the plant mass;
- Locations of passive gas vents and control structures;
- Fire suppression using pumper trucks;
- Security;
- Area to be burned; and
- Ambient conditions, including wind conditions, humidity, temperature.

### **7.3.2 Field Verification**

Four areas have already been identified on the Landfill that have suitable thickness of vegetative cover (defined in Section 5.3.1 as a minimum of 2 foot of soil over the clay cap). However, other potential areas for development of woody vegetation will also be examined to determine if they are currently acceptable. Hand augering, drilling, or use of topographic records will be used to determine the thickness of vegetative soil cover layer. Care will be taken not to penetrate the compacted clay cap during any invasive activities. In addition, hand augering will be utilized within 20 feet of the general perimeter of suitable areas to accurately define the extent of suitable planting areas. The FPD will voluntarily conduct these activities, and does not plan to seek Agency input prior to the field verification.

Areas that do not currently have a vegetative cover that meet the two-foot criteria may be amended with the placement of additional vegetative soil. As previously noted, suitable new vegetative soil cover consists of uncompacted sandy or silty soils that are covered with a minimum of six inches of topsoil. A licensed surveyor will document the suitable planting areas.

### **7.3.3 Woody Vegetation Implementation**

Once the areas with suitable vegetative cover have been delineated, the overall planting scheme and implementation schedule will be developed. A formalized planting strategy and implementation plan will include, but not be limited to, the following:

- A map of the landfill indicating areas of planting and species (trees and other vegetation) to be planted;
- The age and number of tree species to be planted;
- Survey staking of the areas to be planted;
- Overall species spacing;
- A planting schedule defining planting seasons;
- Proper silvicultural practices to be employed during planting;
- Weed control and protection from animals and vandalism;
- Fertilization and irrigation;
- Site specific procedures for conducting prairie burns, if burns are determined to be suitable for site conditions. This would include a health and safety plan and a contingency plan developed by qualified personnel, to protect human health, the landfill and its remedial components, and the surrounding environment during controlled burns; and

- Replacement strategy for trees that do not survive the initial implementation.

The implementation plan will also describe the required site preparation activities. For example, unsuitable trees, shrubs and grasses will be identified and marked. The unsuitable vegetation, including viable roots, will then be removed, and the vegetative cover soil repaired and revegetated with replacement trees or grass. Moreover, at this time, soil samples may be analyzed, if deemed necessary by an ecologist, to determine if the soil will need to be amended with nutrients, through application of fertilizer, to promote healthy tree growth. Following site preparation, the woody vegetation would be planted in the specified areas of suitable vegetative cover.

### **7.3.4 Long –Term Maintenance and Monitoring**

The long term maintenance and monitoring program may be described as a three-phase approach, consisting of regular maintenance, periodic evaluation, and documentation, which are detailed in the following sections.

#### **7.3.4.1 Regular Maintenance**

The establishment of a healthy, self-sustaining ecosystem on the Blackwell Landfill will require regular maintenance that will be dependent upon the species and diversity of grasses and woody plants planted on the landfill. The FPD has personnel who have experience maintaining native prairie and woody vegetation.

Scheduled activities for woody vegetation may include, but are not limited to, regular irrigation during extended dry periods, protection from vandalism and animals, pest control, pruning, and mulching of trees as part of regular maintenance activities performed in the rest of the Blackwell Forest Preserve. If windthrow occurs, toppled trees will be identified and removed promptly. Although it is unlikely that windthrow would cause damage to the clay cap, an assessment of potential damage must be made. Appropriate repairs to the clay cap and vegetative cover soil will be made if necessary.

Primary maintenance for a Eurasian Meadow may consist of mowing one to two times a year. Primary maintenance for Native Prairie may consist of mowing one to two times a year, or controlled burns. Mowing would control the establishment of woody plants in undesirable locations on the cover. However, timing of the mowing is important to the survival of any ground-nesting birds; it should not take place before July 15<sup>th</sup> to allow the birds to leave their nests. The aesthetic appearance of the cover would be greatly enhanced if the hay were removed after mowing. Qualified personnel would conduct the controlled burns when appropriate, in accordance with site specific procedures for the protection of human health, the remedial components at Blackwell Landfill, and the surrounding environment.

#### **7.3.4.2 Periodic Evaluation**

A regular assessment of the restoration strategy should be provided at five-year intervals. This assessment should note the early success of germination of species, and document the dilatory development of species. The planting is likely to respond differently in different areas of the restoration, particularly where slopes are as steep as those found on Mount Hoy. It is probable that many areas will need to be augmented with additional species to maintain diversity. The selection of species will depend on which matrix species are adapting best. If deemed appropriate, nutrient levels in the vegetative cover soils should be analyzed and adjusted accordingly through the application of fertilizer (e.g., pH, magnesium, calcium, phosphorus, potassium, nitrate, ammonia, conductivity, copper, iron, zinc, and manganese). In addition, the inspections should include an evaluation of whether the trees have adequate protection from disease, animals, or vandalism.

To evaluate the effects of deep-rooted grasses and tree roots on Blackwell's clay cap, a root penetration study shall also be conducted at five-year intervals. The primary study will be conducted on selected trees and selected grass species that will be excavated in order to examine root growth and clay cap condition. Trees will be selected for excavation based upon the height, age, and planting density of the tree and shrub species. The study will also be conducted on dead or dying trees. If damage to the clay cap exists, the probable cause of the damage will be determined. Once the cause of any clay cap damage has been ascertained, the current vegetation in that area will be re-evaluated, and changes in vegetation types will be conducted during appropriate planting times.

In addition, successful establishment of a low maintenance, highly diversity ecosystem requires the identification and removal of invasive, non-native grass and tree species that will be detrimental to a woodland environment. In a study conducted by Robinson and Handel (1995), one year after planting 17 different species on Fresh Kills Landfill, birds had introduced 20 new species. The authors believed that the addition of the planted trees added perching locations for fruit-eating birds that would not normally perch below 1.5 to 2 meters. The authors concluded that in general, for every three installed plants, natural dispersion added a new individual to the community during the first year of the study. Therefore, the areas surrounding woody vegetation establishment will require monitoring to ensure that grasses and woody vegetation volunteers do not grow outside the area boundaries, and that only suitable species remain. Examples of the invasive grass species include crown vetch (*Coronilla varia*) or bird's foot trefoil (*Lotus corniculatus*). Their weak root system may not be able to prevent erosional gullies from developing. A variety of methods for the removal of invasive species may need to be considered.

#### **7.3.4.3 Documentation**

The regular maintenance and five year monitoring of the restoration strategy will be documented. The regular maintenance documentation will summarize scheduled, as well as unscheduled, maintenance. The five year monitoring report will describe the current grass and woody vegetation conditions on the landfill, provide an overall summary of regular maintenance and the results of the root penetration study, and provide recommended modifications to the regular maintenance program or the restoration strategy.

## 8.0 CONCLUSIONS

The purpose of this Arboreal Study is to present an evaluation of tree growth on landfills, and to demonstrate that if properly implemented, trees will not harm the integrity of the existing clay cap at Blackwell Landfill. The study consisted of a literature review, a multiphase root penetration study, and a review of current growing conditions on the Landfill. The study concluded that only two feet of vegetative soil cover is required to support tree growth and protect the integrity of the underlying compacted clay cap. The study also identified four areas on the Landfill that have a sufficient thickness of vegetative soil cover to support tree growth, although additional areas of suitable soil cover could be identified by further investigative activities or through the placement of additional soil.

The review of growing conditions on the Landfill indicated that over 250 individual woody plants were growing on the landfill. However, most trees were growing in areas where there was no documentation of sufficient soil cover thickness. Some tree and grass species were considered unsuitable for the Landfill because of their invasive nature.

The Arboreal Study identified three woody vegetation options for the Landfill. They are:

- 1) removal of all woody vegetation currently growing on the landfill;
- 2) removal of all unsuitable vegetation from the landfill. This would include the removal of unsuitable species from the areas of sufficient soil cover thickness, and removal of all woody vegetation from the remaining areas of the Landfill that do not have sufficient soil cover thickness; and
- 3) establishment of additional woody vegetation on the landfill in areas of sufficient soil cover thickness.

The Arboreal Study outlined the development of a future restoration strategy for the Blackwell Landfill that would include selection of appropriate grass and tree species, a planting strategy, field verification, woody vegetation implementation, maintenance and long-term monitoring. Specific details of the restoration strategy will be provided in a follow up report entitled "Comprehensive Restoration Strategy for Woody Vegetation Implementation at Blackwell Landfill."

## 9.0 REFERENCES

(Copies of most referenced documents are provided in Appendix D)

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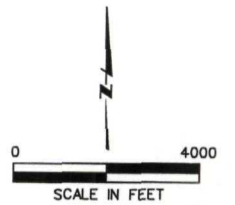
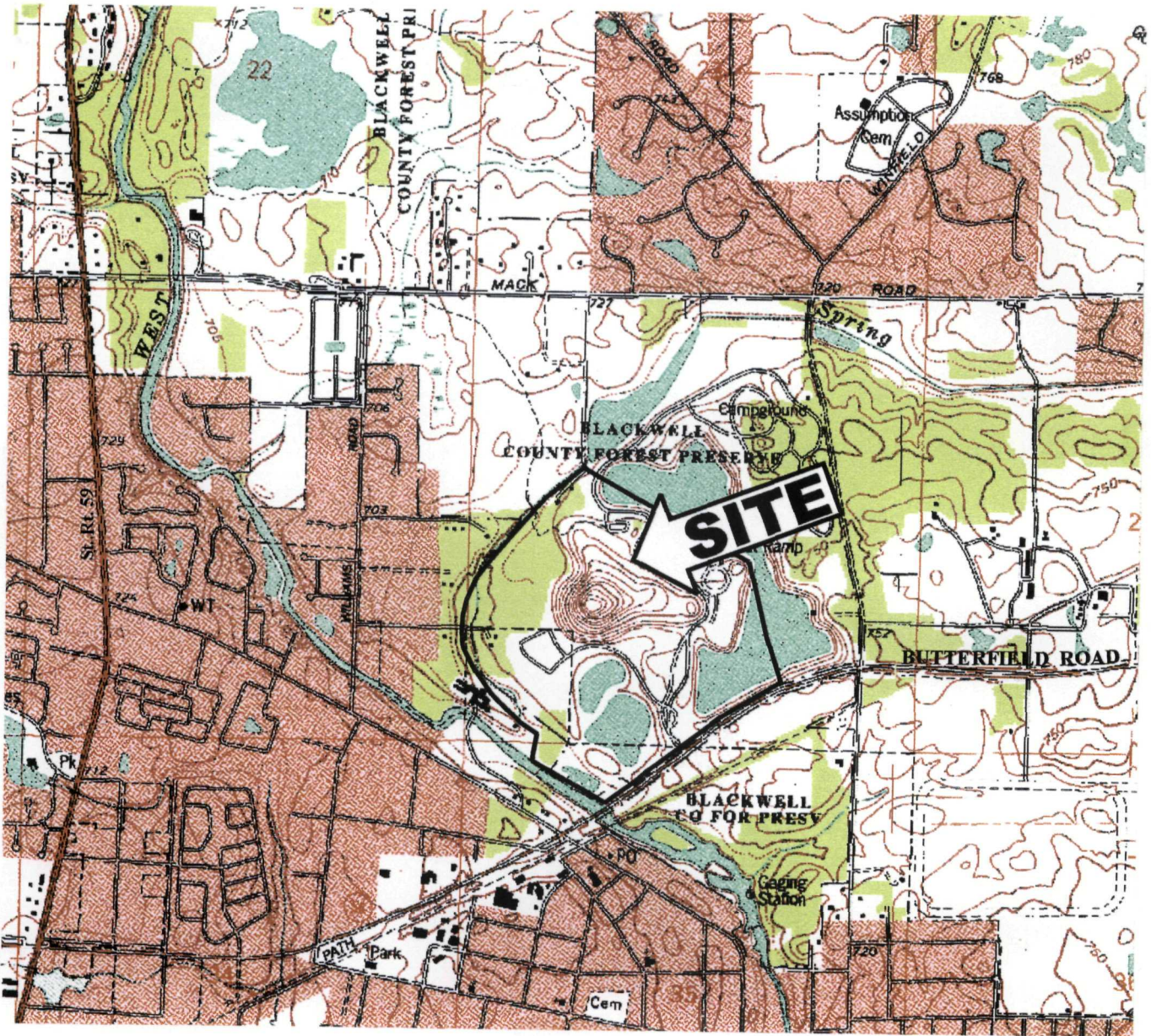
**Table 1**  
**Summary of Field Investigation for the Root Penetration Study<sup>(1)</sup>**  
**Arboreal Study**  
**Forest Preserve District of DuPage County**  
**Blackwell Landfill NPL Site**

Location	Common Name	Latin Name	Height (feet)	DBH <sup>(2)</sup> (inches)	Excavation Depth (feet)	Taproot Present ?	Depth to Compacted Clay (feet)	Maximum Root Depth (feet)
50 ft SE of EW08	Eastern Red Cedar	<i>Juniperus virginiana crebra</i>	10.5	2.0	2.8	No	2.4	1.5
75 ft E of EW08	Slippery Elm	<i>Ulmus rubra</i>	10.5	2.5	2.4	No	1.5	1.6 <sup>(3)</sup>
250 ft E of SV12	Smooth Sumac	<i>Rhus glabra</i>	10.8	2.5	2.0	No	not encountered	1.3
adjacent to Smooth Sumac	Silver Maple	<i>Acer saccharinum</i>	15.0	4.0	4.5	No	not encountered	<4.5 <sup>(4)</sup>
100 ft S of SV12	Honey Locust	<i>Gleditsia triacanthos</i>	10.0	2.0	2.8	No	2.8	2.3

**Notes:**

1. Field investigation conducted by Montgomery Watson and Conservation Design Forum on December 8, 1998.
2. DBH = Diameter at Breast Height (4.5 ft above ground surface)
3. The deepest root observed was not the tap root, but a smaller, secondary root.
4. The deepest root observed was not a tap root, but a smaller, secondary root.



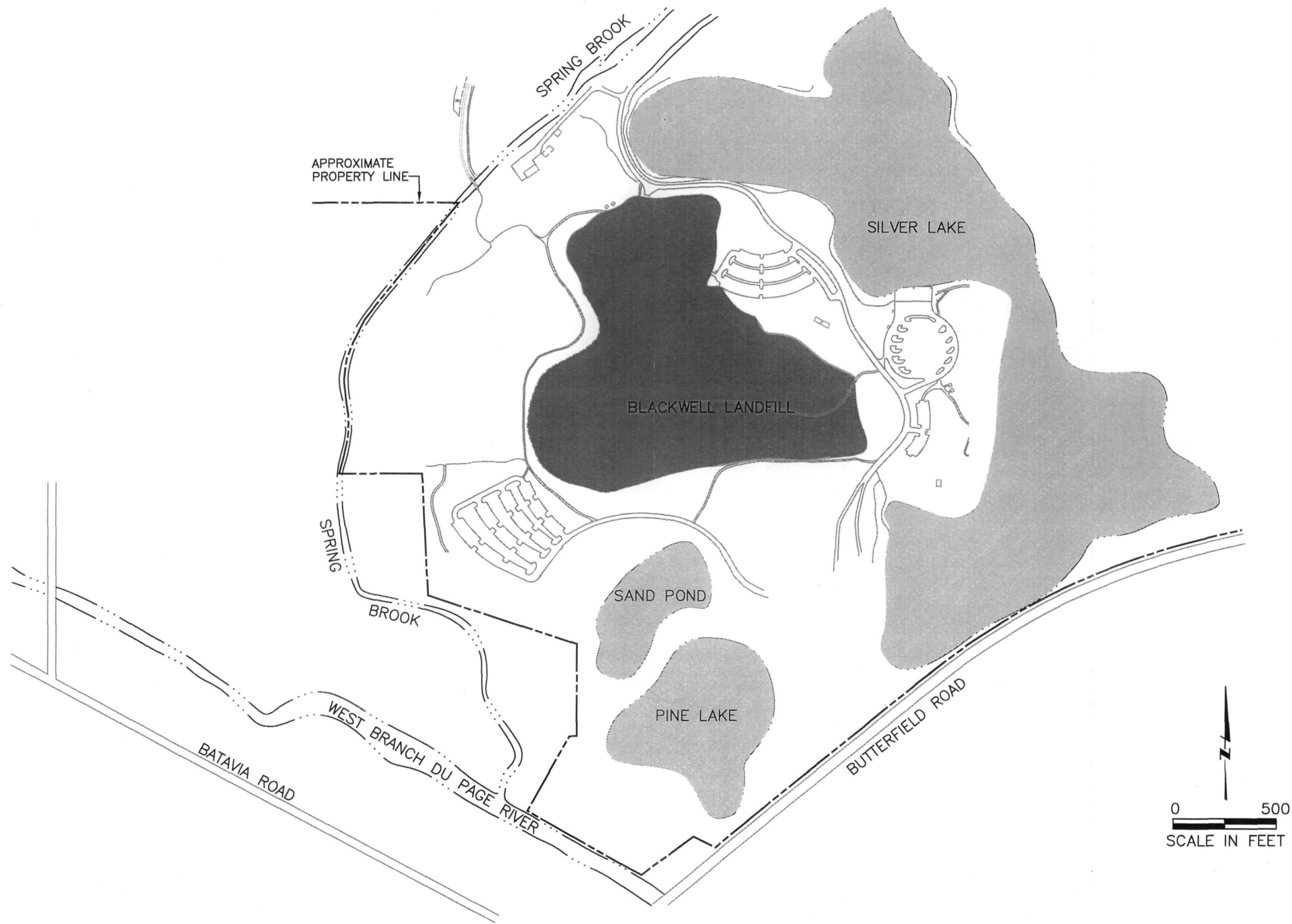


**MONTGOMERY WATSON**  
Chicago, Illinois

BLACKWELL LANDFILL  
NPL SITE  
DUPAGE COUNTY, ILLINOIS

SITE LOCATION MAP

FIGURE  
**1**



SCALE 1" = 500'	 <b>MONTGOMERY WATSON</b> Chicago, Illinois	BLACKWELL LANDFILL NPL SITE DU PAGE COUNTY, ILLINOIS	SITE FEATURE MAP	FIGURE 2
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Plot Date:

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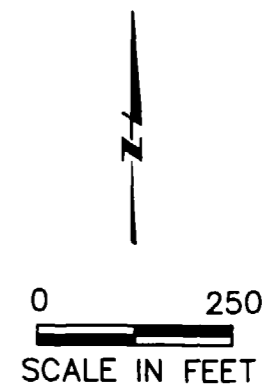


#### LEGEND

— LIMITS OF REFUSE BASED ON GEOPHYSICAL TESTING AND SOIL BORINGS

#### NOTE

1. THE TOPOGRAPHIC MAP DOES NOT TAKE INTO ACCOUNT GRADE CHANGES IN AREA OF CAP REPAIR.



SCALE  
AS SHOWN



BLACKWELL LANDFILL NPL SITE  
DUPAGE COUNTY, ILLINOIS

TOPOGRAPHIC MAP (1992)

FIGURE  
3

Plot Date: 11/9/99

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# LEGEND

- MH-6 MANHOLE LOCATION AND NUMBER WITH LIQUID CUTOFF TRENCH AND PIPE
- EW01 LEACHATE EXTRACTION WELL/GAS VENT LOCATION AND NUMBER
- LIMITS OF REFUSE BASED ON GEOPHYSICAL TESTING AND SOIL BORINGS
- LS1 LIFT STATION LOCATION AND NUMBER
- LEACHATE PRESSURE CONVEYANCE PIPE AND CONTROL WIRE
- LEACHATE GRAVITY CONVEYANCE PIPE AND DIRECTION
- GAS HEADER PIPE, LENGTH, SLOPE AND DIRECTION
- DL01 DRIPLEG LOCATION AND NUMBER
- DV-8 VENT PIPE LOCATION AND NUMBER
- unit 1 SEPTEMBER 1999 SITE RECONNAISSANCE

## NOTES

1. APPROXIMATE LIMITS OF REFUSE HAVE BEEN ESTIMATED BASED ON INFORMATION PRESENTED IN THE PREDESIGN REPORT, APRIL 1997.
2. COVER MATERIALS WERE MAPPED USING SOIL BORING DATA WAS COMPILED FROM THE FOLLOWING SOURCES:
  - TESTING SERVICE CORPORATION, CAROL STREAM, ILLINOIS, "BLACKWELL FOREST PRESERVE DEEP VENTS AND EXPLORATORY BORINGS," OCTOBER 1, 1988.
  - MONTGOMERY WATSON, ADDISON, ILLINOIS, "REVISED PREDESIGN REPORT," JULY 1997.
  - MONTGOMERY WATSON, ADDISON, ILLINOIS, "PREDESIGN INVESTIGATION," DECEMBER 1996.

0 250  
SCALE IN FEET

REV	DATE	BY	DESCRIPTION

SCALE	WARNING
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	IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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DRAWN	
CHECKED	

SUBMITTED BY:	
(PROJECT MANAGER)	
DATE	
(PROJECT ENGINEER)	
LICENSE NO.	
DATE	



**MONTGOMERY WATSON**  
Chicago, Illinois

BLACKWELL LANDFILL NPL SITE  
DU PAGE COUNTY, ILLINOIS

1999 FIELD RECONNAISSANCE

FIGURE  
4



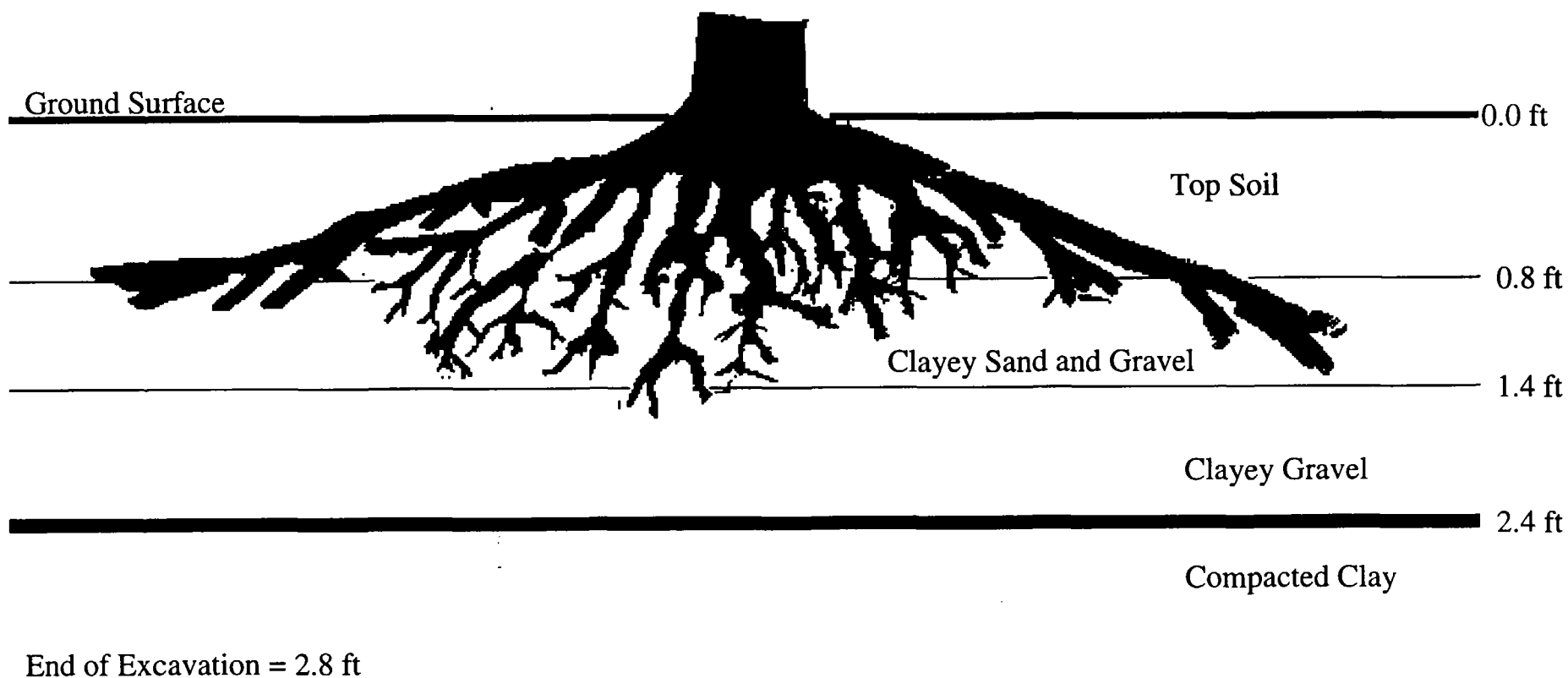


# Eastern Red Cedar

Tree Height = 10.5 ft

DBH = 2.0 in

Maximum Depth of Root Penetration = 1.5 ft



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BLACKWELL LANDFILL NPL SITE  
DU PAGE COUNTY, ILLINOIS

ROOT PENETRATION RESULTS

FIGURE

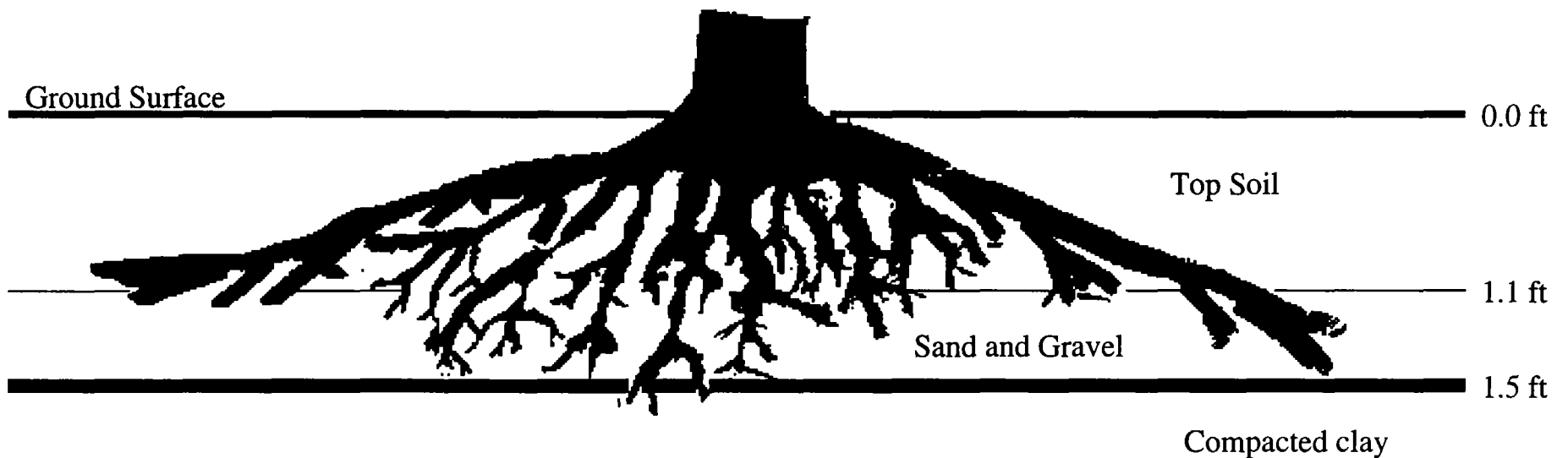
7

# Slippery Elm

Tree Height = 10.5 ft

DBH = 2.5 in

Maximum Depth of Root Penetration = 1.6 ft



End of Excavation = 2.4 ft



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DU PAGE COUNTY, ILLINOIS

ROOT PENETRATION RESULTS

FIGURE  
8

# Smooth Sumac

Tree Height = 10.8 ft

DBH = 2.5 in

Maximum Depth of Root Penetration = 1.3 ft

Ground Surface

0.0 ft

Top Soil

1.3 ft

Clay and gravel fill

End of Excavation = 2.0 ft



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Chicago, Illinois

BLACKWELL LANDFILL NPL SITE  
DU PAGE COUNTY, ILLINOIS

ROOT PENETRATION RESULTS

FIGURE

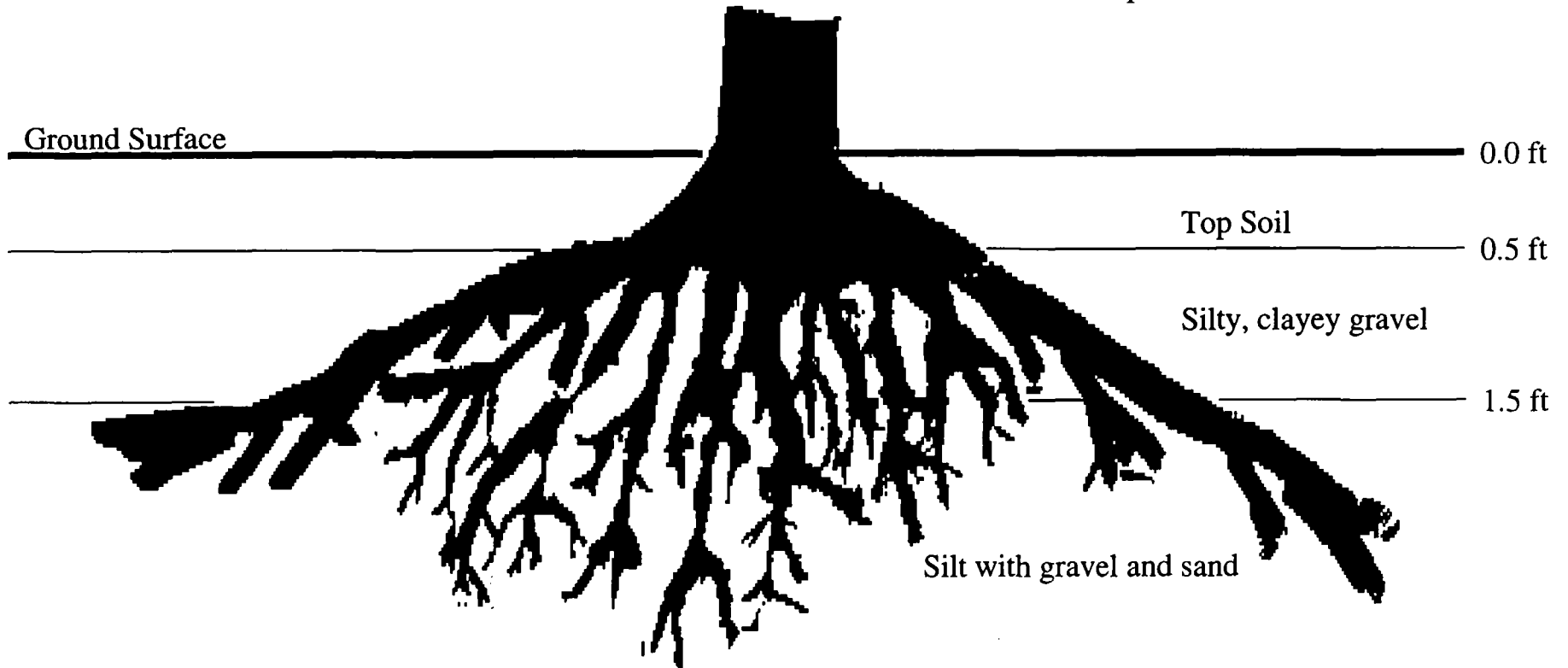
9

# Silver Maple

Tree Height = 15.0 ft

DBH = 4.0 in

Maximum Depth of Root Penetration = >4.5 ft



End of Excavation = 4.5 ft



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ROOT PENETRATION RESULTS

FIGURE

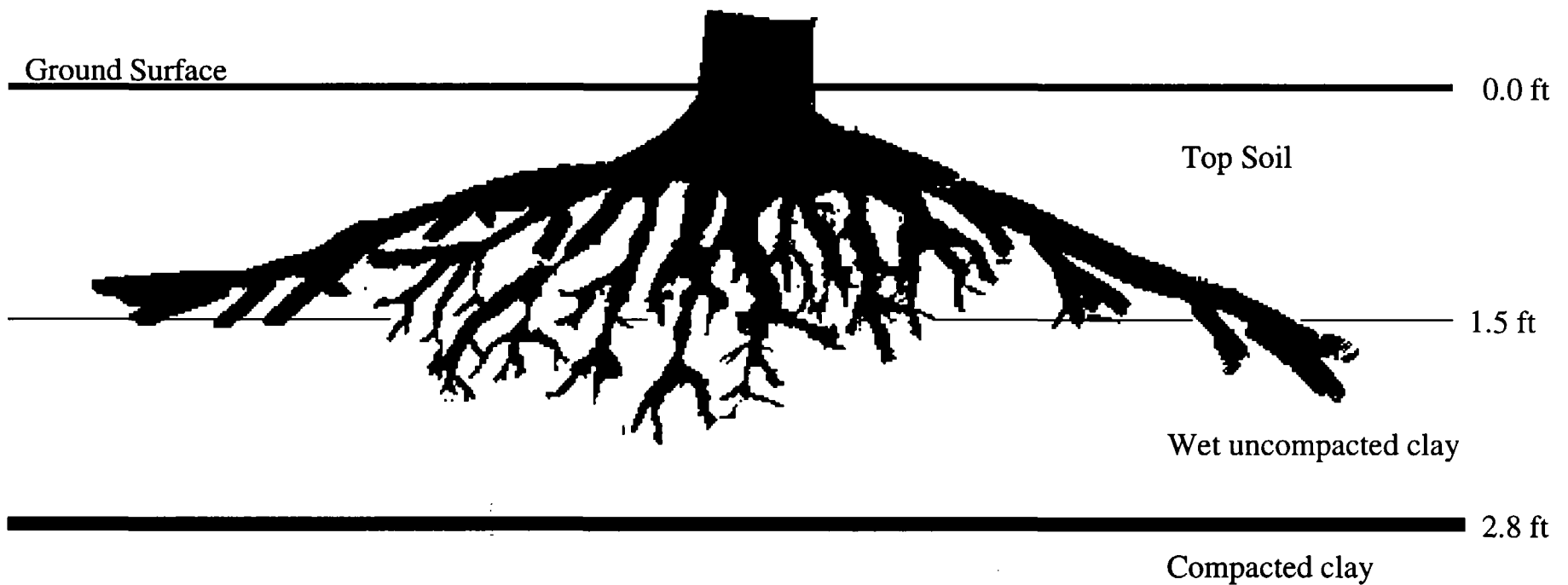
10

# Honey Locust

Tree Height = 10.5 ft

DBH = 2.0 in

Maximum Depth of Root Penetration = 2.3 ft



End of Excavation = 2.8 ft



**MONTGOMERY WATSON**  
Chicago, Illinois

BLACKWELL LANDFILL NPL SITE  
DU PAGE COUNTY, ILLINOIS

ROOT PENETRATION RESULTS

FIGURE

11



A



**Appendix A**  
**Woody Species Report for the Blackwell Forest Preserve Landfill Site (Conservation  
Design Forum)**



## CONSERVATION DESIGN FORUM

Landscape Architecture • Community Planning • Ecological Restoration • Resource Management

324 North York Road  
Elmhurst, Illinois 60126  
630.758.0355 phone  
630.758.0320 fax  
cdf@cdfinc.com

### Woody Species Report for the Blackwell Forest Preserve Landfill Site

October 28, 1998  
September 23, 1999

#### EXECUTIVE SUMMARY

On 28 October 1998 and 23 September 1999, staff ecologists from Conservation Design Forum assessed the woody vegetation across the Blackwell Forest Preserve Landfill Site. In 1998, 4 areas with woody plants were evaluated and in 1999, 14 units were assessed (see map exhibit). Most of the trees and shrubs volunteered from seed and vegetative propagation. It is possible that some of the pines were planted after the landfill was closed in the middle 1970's. The average age of this woody growth is approximately 10 to 15 years old. From a vegetative standpoint, none of the landfill represents remnant vegetation (see addendum).

A total of 27 species of woody plants (trees and shrubs) were noted on the landfill site. Fifteen (56%) are native to this region and twelve (44%) are considered non-native. In 1999, approximately 250 individual woody plants with diameters at breast height (dbh) greater than 2" growing on the landfill were noted. The largest on the site was an eastern cottonwood that measured 14" dbh and 25' tall. It is located in Unit 6. Along with these trees there are numerous saplings and seedlings of such species as box elder, cottonwood, common buckthorn, lombardy poplar, sumacs, etc. The species with the most individuals recorded over 2" dbh was green ash with approximately 65 counted. The next most common species was the lombardy poplar with approximately 35 recorded. Many of the lombardy poplars were in poor condition or already dead. Lombardy poplars are upright, fast growing, weedy cultivars that can grow to 70 to 90' with a spread of 10 to 15' in 20 to 30 years. However, these trees seldom attain this size because of a canker disease (*Dothichiza populnea*) that develops in the upper branches and trunk for which there is no cure.

A total of 57 species of herbaceous plants were recorded on the landfill site. Of these 22 (39%) are native and 35 (61%) are non-native. The most prevalent herbaceous species are all non-native grasses – tall fescue (*Festuca elatior*), followed by perennial rye (*Lolium perenne*) and Kentucky blue grass (*Poa pratensis*).

## 1998 ASSESSMENT

On October 28, 1999, four discrete areas of the landfill that had trees present were evaluated. Most of the landfill site has very few trees, and those that are present most likely volunteered from seed or vegetative propagation. It was apparent that a few of the trees had been planted. Table 1 is a listing of the occurrences of the woody plants that were noted on or near the four areas.

Table 1. Distribution of trees and shrubs on the Blackwell Landfill Site, shaded cells = trees near the edge.

COMMON NAME ( <i>Species</i> )	Native/ Adventive	Excavated	#1	#2	#3	#4
GRAY DOGWOOD ( <i>Cornus racemosa</i> )	N		x	x		x
SCARLET HAWTHORN ( <i>Crataegus coccinea</i> )	N			x		
COCKSPUR HAWTHORN ( <i>Crataegus crus-galli</i> )	N		x			
AUTUMN OLIVE ( <i>Elaeagnus umbellata</i> )	A		x	x		x x
RED CEDAR ( <i>Juniperus virginiana cerebra</i> )	A	X		x		x x
COMMON PRIVET ( <i>Ligustrum vulgare</i> )	A		x			
SHOWY FLY HONEYSUCKLE ( <i>Lonicera X bella</i> )	A		x			x
WHITE PINE ( <i>Pinus strobus</i> )	N		x	x		
WHITE POPLAR ( <i>Populus alba</i> )	A		x	x		x
LOMBARDY POPLAR ( <i>Populus nigra italica</i> )	A		x	x		x
COMMON BUCKTHORN ( <i>Rhamnus cathartica</i> )	A		x	x		x x
MULTIFLORA ROSE ( <i>Rosa multiflora</i> )	A		x			
SLIPPERY ELM ( <i>Ulmus rubra</i> )	N	X	x			x
<b>Additional tree species observed on the landfill (partial list):</b>						
BOX ELDER ( <i>Acer negundo</i> )	N					
SILVER MAPLE ( <i>Acer saccharinum</i> )	N	X				
WHITE ASH ( <i>Fraxinus americana</i> )	N					
GREEN ASH ( <i>Fraxinus pensylvanica subintegerrima</i> )	N					
HONEY LOCUST ( <i>Gleditsia triacanthos</i> )	N	X				
AMUR HONEYSUCKLE ( <i>Lonicera maackii</i> )	A					
EASTERN COTTONWOOD ( <i>Populus deltoides</i> )	N					
SMOOTH SUMAC ( <i>Rhus glabra</i> )	N	X				

## VEGETATION CHARACTERIZING THE FOUR UNITS ON THE BLACKWELL LANDFILL SITE

### **Area 1**

Dominant herbaceous species:

*Festuca elatior* (tall fescue), *Phleum pratense* (timothy), *Plantago rugelii* (red-stalked plantain),  
*Poa pratensis* (Kentucky blue grass)

Woody species (inside the flags):

*Cornus racemosa* (gray dogwood), *Crataegus crus-galli* (cockspur hawthorn), *Elaeagnus umbellata* (autumn olive), *Ligustrum vulgare* (common privet - sapling), *Lonicera x bella* (showy fly honeysuckle), *Pinus strobus* (white pine - planted along the east side of the fence), *Populus alba* (white poplar - clone), *Populus nigra italica* (lombardy poplar - clone), *Rhamnus cathartica* (common buckthorn), *Rosa multiflora* (multiflora rose), *Ulmus rubra* (slippery elm)

### **Area 2**

Dominant herbaceous species:

*Bromus inermis* (Hungarian brome), *Festuca elatior* (tall fescue), *Lolium perenne* (perennial rye grass)

Woody species (inside the flags):

*Cornus racemosa* (gray dogwood - seedlings along fence), *Crataegus coccinea* (scarlet hawthorn - 1), *Elaeagnus umbellata* (autumn olive - 1 seedling, 4+ trees), *Juniperus virginiana crebra* (red cedar - 6), *Pinus strobus* (white pine - 1), *Populus alba* (white poplar - clone), *Populus nigra italica* (lombardy poplar - clone), *Rhamnus cathartica* (common buckthorn - 3)

### **Area 3**

Dominant herbaceous species:

*Festuca elatior* (tall fescue), *Lolium perenne* (perennial rye grass), *Poa pratensis* (Kentucky blue grass)

### **Area 4**

Dominant herbaceous species:

*Festuca elatior* (tall fescue), *Lolium perenne* (perennial rye grass), *Poa pratensis* (Kentucky blue grass), *Setaria faberi* (giant foxtail)

Woody species (inside the flags):

*Elaeagnus umbellata* (autumn olive - seedling), *Juniperus virginiana cerebra* (red cedar), *Populus alba* (white poplar - clone), *Rhamnus cathartica* (common buckthorn), *Ulmus rubra* (slippery elm)

Woody species (just outside the flags):

*Acer saccharinum* (silver maple), *Cornus racemosa* (gray dogwood), *Elaeagnus umbellata* (autumn olive), *Gleditsia triacanthos* (honey locust), *Juniperus virginiana cerebra* (red cedar), *Lonicera x bella* (showy fly honeysuckle), *Populus nigra italica* (lombardy poplar), *Rhamnus cathartica* (common buckthorn)

Additional vegetation found on the Blackwell Landfill Site (partial list):

*Acer negundo* (box elder - 3), *Agropyron repens* (quack grass), *Aster pilous* (hairy aster), *Coronilla varia* (crown vetch), *Fraxinus pennsylvanica subintegerrima* (green ash - seedling), *Populus deltoides* (eastern cottonwood), *Rhus glabra* (smooth sumac - clonal), *Solidago altissima* (tall goldenrod)

### 1999 ASSESSMENT

On September 23<sup>rd</sup>, 1999, the woody vegetation across the Blackwell Landfill Site was qualitatively assessed. The methodology agreed upon was to conduct a systematic meander across the landfill in order to characterize all areas of woody growth. The information recorded included species present, size of largest individuals in diameter at breast height (DBH) and estimated height, and numbers of stems present. Table 2 is a summary of the assessment. During the site visit, a list of all of the vegetation seen across the landfill was noted in order to determine the floristic quality of the area as a whole (see Table 3).

Table 2. Summary table of the trees inventoried 1999 at the Blackwell landfill site.

Unit	Species	Native/ Adventive	Number of Trees	Largest Tree dbh/height	Saplings > 2" dbh
1	GREEN ASH ( <i>Fraxinus pennsylvanica subintegerrima</i> )	N	15	12"/25'	
2	HONEY LOCUST ( <i>Gleditsia triacanthos</i> )	N	5	8"/20'	10 saplings
3	WHITE PINE ( <i>Pinus strobus</i> )	N	4	6"/12"	
3	STAGHORN SUMAC ( <i>Rhus typhina</i> )	N			thicket
4	SCOTCH PINE Scotch pine ( <i>Pinus sylvestris</i> )	A	2	5"/12'	
5	BOX ELDER ( <i>Acer negundo</i> )	N	1	11"/15'	
5	EASTERN COTTONWOOD ( <i>Populus deltoides</i> )	N	1	8"/20"	
6	BOX ELDER ( <i>Acer negundo</i> )	N	5	8"/25'	
6	SILVER MAPLE ( <i>Acer saccharinum</i> )	N	6	6"/20'	@30 saplings

Unit	Species	Native/ Adventive	Number of Trees	Largest Tree dbh/height	Saplings > 2" dbh
6	WHITE ASH ( <i>Fraxinus americana</i> )	N	6	4"/15'	
6	GREEN ASH ( <i>Fraxinus pennsylvanica subintegerrima</i> )	N	@65	10"/20'	
6	HONEY LOCUST ( <i>Gleditsia triacanthos</i> )	N	5	8"/25'	@35 saplings
6	EASTERN COTTONWOOD ( <i>Populus deltoides</i> )	N	1	14"/25'	10 saplings
6	LOMBARDY POPLAR ( <i>Populus nigra italica</i> )	A	@35	8"/25'	
6	BLACK LOCUST ( <i>Robinia pseudoacacia</i> )	A	5	8"/25'	12 saplings
7	GREEN ASH ( <i>Fraxinus pennsylvanica subintegerrima</i> )	N	12	4"/15'	
7	BOX ELDER ( <i>Acer negundo</i> )	N	6	6"/20'	
7	WHITE ASH ( <i>Fraxinus americana</i> )	N	4	4"/20'	
7	COMMON BUCKTHORN ( <i>Rhamnus cathartica</i> )	A			5 saplings
7	RED CEDAR ( <i>Juniperus virginiana crebra</i> )	N	6	3"/10'	
8	SILVER MAPLE ( <i>Acer saccharinum</i> )	N	6	4"/20'	
8	HONEY LOCUST ( <i>Gleditsia triacanthos</i> )	N	12	4"/20'	
8	LOMBARDY POPLAR ( <i>Populus nigra italica</i> )	A			@10 saplings
9	RED OAK ( <i>Quercus rubra</i> )	N	1	4"/20'	
9	WHITE PINE ( <i>Pinus strobus</i> )	N	1	8"/20'	
9	RED CEDAR ( <i>Juniperus virginiana crebra</i> )	N	6	3"/10'	
10	BOX ELDER ( <i>Acer negundo</i> )	N	1	4"/20'	
10	RED CEDAR ( <i>Juniperus virginiana crebra</i> )	N			8 saplings
10	WHITE PINE ( <i>Pinus strobus</i> )	N	10	3"/12'	
10	LOMBARDY POPLAR ( <i>Populus nigra italica</i> )	A			@10 saplings
11	SCARLET HAWTHORN ( <i>Crataegus coccinea</i> )	N			grove
11	SMOOTH SUMAC ( <i>Rhus glabra</i> )	N			thicket
12	COMMON BUCKTHORN ( <i>Rhamnus cathartica</i> )	A			6 saplings
13	BOX ELDER ( <i>Acer negundo</i> )	N	4	4"/15'	
13	EASTERN COTTONWOOD ( <i>Populus deltoides</i> )	N	1	8"/20'	
14	WHITE PINE ( <i>Pinus strobus</i> )	N	24	12"/25'	

### QUALITATIVE ASSESSMENT OF WOODY VEGETATION

A total of 14 woody vegetation "units" were identified. Each is described below and their locations depicted on the exhibit.

#### **Unit 1**

Unit 1 is a line of 15 green ash trees that were planted within a parking lot "island" approximately 15 years ago. The largest tree is 12"dbh/25'tall. A few of the smaller trees are dead.

## **Unit 2**

Unit 2 is a line of 5 honey locust trees located along the north berm of the landfill, immediately north of Unit 1. The largest tree is 8"dbh/20'tall. There are approximately 10 young saplings located within the tree line as well, all less than 2"dbh.

## **Unit 3**

Unit 3 is a thicket of staghorn sumac located along the northwest edge of the slope. All of the stems are less than 2"dbh, and the average height of the clone is 15'. Approximately 4 white pine trees are growing within the thicket. All are approximately 6"dbh/12'tall.

## **Unit 4**

Unit 4 contains 2 Scotch pine trees located along the western slope. Both are 5"dbh/12'tall.

## **Unit 5**

Unit 5 is located along the southwest corner of the landfill. The trees and shrubs include 1 box elder, 11"dbh/15'tall; 1 eastern cottonwood, 8"dbh/20'tall; and several saplings of these two species and saplings of common buckthorn and lombardy poplar. These saplings are on average 1"dbh/10'tall. Most of the lombardy poplar are dead.

## **Unit 6**

Unit 6 is the tree line that extends across the base of the southern slope of the landfill. Several different species of trees and shrubs are found within this unit. The largest individual of each tree species is listed below, along with a general assessment the species presence within the unit.

- box elder: 8"dbh/25'tall.

There are approximately 4 multi-stemmed trees that average 4"dbh/20'tall.

- silver maple: 6"dbh/20'tall.

There are approximately 5 multi-stemmed trees that average 4"dbh/20'tall and approximately 30 saplings that average 2"dbh/10'tall.

- white ash: 4"dbh/15'tall.

There are approximately 5 more trees of similar size.

- green ash: 10"dbh/20'tall.

This is the most common tree species within the unit. There are approximately 30 trees that average 6"dbh/15'tall and several dozen that average 3"/10'tall.

- honey locust: 8"dbh/25'tall.

There are approximately 5 multi-stemmed trees that average 4"dbh/15'tall and several dozen saplings that average 1"dbh/10'tall.

- eastern cottonwood: 14"/25'tall.

There are about 10 saplings that average 2"dbh/10'tall.

- lombardy poplar: 8"dbh/25'tall.

There are several dozen saplings and small trees, many of which are dead or nearly so; overall, these average 3"dbh/15'tall.

- black locust: 8"dbh/20'tall.

There are approximately 5 smaller trees that average 4"dbh/15'tall and a dozen saplings that average 1"dbh/10'tall.

Throughout the "understory" are various saplings of these trees along with shrubs of gray dogwood, autumn olive, Eurasian honeysuckles, common buckthorn, and smooth sumac. Of these shrubs, common buckthorn is the most frequent and has an average size of approximately 2"dbh/10'tall.

#### **Unit 7**

Unit 7 comprises isolated trees along the southern slope of the landfill. These include approximately 12 green ash that average 4"dbh/15'tall; 6 box elder that average 6"dbh/20'tall; 4 white ash that average 4"dbh/20'tall; and 6 eastern red cedar that average 3"dbh/10'tall. Scattered around these trees are several saplings of common buckthorn.

#### **Unit 8**

Unit 8 corresponds to the woody vegetation to the "1998 Area #4," and includes 6 silver maples that average 4"dbh/20'tall; 12 honey locust that average 4"dbh/20'tall; and several lombardy poplars that average 2"dbh/15'tall. Several shrubs are located around these trees and include gray dogwood, autumn olive, Eurasian honeysuckles, and Siberian elm.

#### **Unit 9**

Unit 9 is located along the eastern boundary of the landfill and includes 1 red oak that is 4"dbh/20'tall; 1 white pine that is 8"dbh/20'tall; and approximately 6 eastern red cedars that average 3"dbh/10'tall. In addition, there are scattered shrubs of gray dogwood and autumn olive.

#### **Unit 10**

Unit 10 corresponds to the "1998 Area #2," and includes 1 box elder 4"dbh/20'tall; 8 scattered eastern red cedars that average 2"dbh/10'tall; approximately 10 white pines that average

3"dbh/12'tall; and several partially-dead lombardy poplars that average 1"dbh/8'tall. In addition, there are 2 multi-stemmed shrub clusters of autumn olive.

#### **Unit 11**

Unit 11 includes a small grove of scarlet hawthorns that average 2"dbh/10'tall, and a thicket of smooth sumac with stems that average 1"dbh/8'tall.

#### **Unit 12**

Unit 12 corresponds to the "1998 Area #3," and includes 6 saplings of common buckthorn, all 1"dbh/4'tall.

#### **Unit 13**

Unit 13 includes approximately 4 box elder that average 4"dbh/15'tall; and an eastern cottonwood that is 8"dbh/20'tall. In addition, there are numerous small shrubs of gray dogwood, autumn olive, eastern red cedar, and common buckthorn all with stems that average 1"dbh/6'tall. There are also many dead stems of lombardy poplar that average 3"dbh/12'tall.

#### **Unit 14**

Unit 14 corresponds to the "1998 Area #1," and includes approximately 24 white pines, the largest of which is 12"dbh/25'tall. In addition, there are several saplings of box elder, Eurasian honeysuckle shrubs, common buckthorn, and dead lombardy poplar.

### **FLORISTIC QUALITY ASSESSMENT**

The results of the composite floristic inventory of the vegetation noted from across the entire landfill is presented at the end of the report. Of the 77 species inventoried, 43% are native. The native mean C and FQI values are 1.8 and 10, respectively (see addendum).

### **PLANT SELECTION CRITERIA**

#### **Wetness Categories**

The U.S. Fish and Wildlife Service (Reed, 1988a) has prepared a list of the wetland plants of the United States and characterized them according to the likelihood they are to be found in wetland or upland areas. With assistance from botanists throughout the country, each species has been assigned one of eleven indicator categories representing a spectrum of habitat preferences from wet to dry. The categories have been tailored to accommodate the species as they are perceived to

grow in each of ten regions in the lower 48 states. The Chicago region is in Region 3, and a volume has been produced that deals directly with local species (Reed, 1988b). The indicator category defines the estimated probability of a species to occur in wetlands. Plants are designated as *Obligate Wetland*, *Facultative Wetland*, *Facultative*, *Facultative Upland*, and [obligate] *Upland*. These categories are defined as follows:

Plant Category	Symbol	Definition
Obligate Wetland	<b>OBL</b>	Occurs almost always in wetlands under natural conditions (estimated > 99% probability).
Facultative Wetland	<b>FACW</b>	Usually occurs in wetlands, but occasionally found in non-wetlands (estimated 67%-99% probability).
Facultative	<b>FAC</b>	Equally likely to occur in wetlands or non-wetlands (estimated 34%-66% probability).
Facultative Upland	<b>FACU</b>	Occasionally occurs in wetlands, but usually occur in non-wetlands (estimated 1%-33% probability).
Upland	<b>UPL</b>	Occurs almost never in wetlands under natural conditions (estimated < 1%).

For about 20% of our flora, "+" or "-" signs have been attached to the three *Facultative* categories to express the exaggerated tendencies for those species. The "+" sign following an indicator category denotes that the species generally has a greater estimated probability of occurring in wetlands than species having the general indicator category, but a lesser estimated probability of occurring in wetlands than those having the next highest general indicator. The "-" sign following an indicator status denotes that the species generally has a lesser estimated probability of occurring in wetlands than species having the general indicator status, but a greater estimated probability of occurring in wetlands than those having the next lowest general indicator.

### Floristic Quality

A standardized tool for use in natural area assessment and referred to as the Floristic Quality Assessment (FQA) was discussed in *Plants of the Chicago Region, 4<sup>th</sup>* (Swink & Wilhelm 1994). The goal of this assessment method was to design a system, based upon plants, that assesses natural quality repeatably and dispassionately, facilitates comparisons among sets of sites, and tracks changes in site quality over time.

This assessment method is based upon a fundamental character of the Chicago region flora itself. It has long been recognized that plants display varying degrees of tolerance to disturbance, as well as varying degrees of fidelity to specific habitat integrity. This concept of species "conservatism" is the basis for the assessment method. The floristic quality of an area is reflected in its inhabitancy by conservative plant species. The basic tool of this method is an evaluation checklist of the plants of the Chicago region. Each native species on the checklist has been given a coefficient of conservatism (C), ranging from 0-10.

In general, the concept can be demonstrated by the following illustrations. Someone shows a specimen of poor man's pepper (*Lepidium virginicum*), and asks, on a scale of 0-10, how confident can one be that the specimen was taken from a remnant natural plant community. The answer would be no confidence, but that in all likelihood it was taken from a highway verge or the edge of a parking lot. Someone else shows rush aster (*Aster borealis*), and there is virtually 100% confidence that it was taken from a remnant fen, and probably one that was not terribly degraded. Another shows sweet-scented bedstraw (*Galium triflorum*); it more than likely came from some sort of remnant wooded area, but little can be said one way or the other about how degraded it is.

In the first case the poor man's pepper can be assigned a C of 0, since there is no confidence that it came from a natural community. Rush aster, on the other hand, can be assigned a C of 10 since there is virtually 100% confidence that it came from an intact natural community. Sweet-scented bedstraw can be given a 5 C value since it is fairly certain that it came from a remnant natural community, but with little confidence that the area was not degraded. This conceptual spectrum can be expressed in a range of scaled values described as coefficients of conservatism. Introduced plants, by their very nature, were uninvolved in the native landscape prior to European settlement, so coefficients of conservatism are not applied to them.

Conservative floristic elements are those native species that, through time, have become adapted to an environment determined by a specific set of biotic and abiotic factors. These factors include local edaphics and extremes of drought, humidity, inundation, fires, temperature, faunal interactions, etc. Though these factors in the aggregate have changed over time, the changes have been gradual enough and buffered sufficiently by system complexity to allow gene pools to adapt. When changes occur rapidly, as they have in the post-settlement period, both species diversity and populations of conservative species on a given tract are diminished in accordance with the severity of the changes. To obtain a qualitative evaluation of an open land site, the indices described by

Swink & Wilhelm (1994) can be applied. According to Swink & Wilhelm, indices obtained are placed in perspective as follows:

*If the Natural Area Rating Index of a given area is 35 or 40, one can be relatively certain that there is sufficient native character to be of rather profound environmental importance in terms of a regional natural area perspective. Areas which rate in the 50's and higher are of paramount importance; such areas are extremely rare, probably occupying less than 0.02 per cent of the total land area in the Chicago Region. Areas which rate less than 35 can usually be assumed to have suffered significantly from abuse or degradation.*

### **Plant Selection**

Plant lists should be specified based upon the conditions of the site, proposed plant community, management, and the long-term goals. However, when selecting a group of plant species to be grown in a native planting, both the wetness and the conservatism categories can aid in the process. By consulting the wetness category for each species, a list of plants can be specified for the localized hydrological conditions.

Plant species can also be specified based upon their coefficient of conservatism. When selecting species for planting into a native planting, it is unlikely that conditions are such that they can support species with high (7 - 10) coefficients of conservatism. On the other hand choosing species with low (0 - 2) coefficients is also inappropriate because it is very likely that these species will volunteer over time. The best range of coefficients to consider for planting are those species with coefficients from 3 to 6.

### **SUMMARY**

The bulleted items below summarize our results.

- 14 Woody Vegetation Units were identified across the landfill.
- Most of these trees and shrubs have volunteered from seed and vegetative propagation. It is possible that some of the pines were planted after the landfill was closed in the middle 1970's.
- The approximately average age of this woody growth is 10 to 15 years old.
- Based on this assessment, the trees that were selected for excavation in 1998 were representative of the trees on the landfill site.
- None of these units, nor any portion of the landfill, represent remnant vegetation.

## REFERENCES

- Reed, P. B., Jr. 1988a. National list of plant species that occur in wetlands: national summary. U.S. Fish Wildl. Serv. Biol. Rep. 88(24). 244 pp.
- Reed, P.B., Jr. 1988b. National list of plant species that occur in wetlands: north central (Region 3). U.S. Fish Wildl. Serv. Biol. Rep. 88(26.3). 99 pp.
- Swink, F. and G. Wilhelm. 1994. Plants of the Chicago region. Indiana Academy of Science. Indianapolis, Indiana.

## ADDENDUM: FLORISTIC QUALITY ASSESSMENT

The inventory data presented below is generated using Wilhelm and Masters's *Floristic Quality Assessment and Computer Applications*, 1999. Plant nomenclature follows Swink and Wilhelm's *Plants of the Chicago Region*, 1994.

**Section 1** includes three tables that summarize the inventory assessment data. The table to the left is an analysis of the floristic quality of the project area. In addition to listing the number of native species and total number of species, the mean coefficient of conservatism (MEAN C), floristic quality index (FQI), and mean wetness (MEAN W) values are presented. These are calculated once for native species only, and a second time including adventive species (W/Adventives). The two other tables summarize the number and percent of species in each physiognomic group (A = annual, B = biennial, P = perennial, W = woody, H = herbaceous).

**Section 2** includes the species inventory arranged alphabetically, with each species preceded by its coefficient of conservatism (C = 0 to 10, weedy to conservative), and followed by its wetness coefficient (W = -5 to +5, wet to dry), corresponding national wetland indicator status (OBL = obligate wetland species, FAC = facultative species, UPL = upland species), physiognomic group, and common name. Adventive species are written in ALL CAPS and have an asterisk (\*) for their C value.

The Mean C is the average coefficient of conservatism for the site. The FQI is derived by multiplying Mean C by the square root of the number of species present. In general, sites with FQI values less than twenty are degraded or derelict plant communities, or are very small habitat remnants. Sites with FQI values in the twenties through low thirties suffer from various kinds of disturbance, but generally have potential for habitat restoration and recovery. When sites have FQI values in the middle thirties or higher, one can be confident that there is sufficient native character present for the area to be at least regionally noteworthy. Sites with indices in the middle forties and higher are often also statewide significant natural areas.

Site: BLACKWELL FOREST PRESERVE LANDFILL SITE  
 Locale: Wheaton, DuPage County, Illinois  
 Date: 28 October 1998 and 23 September 1999  
 By: Conservation Design Forum

## SECTION 1. SUMMARY TABLES

FLORISTIC QUALITY DATA	Native	37	44.0%	Adventive	47	56.0%
37 NATIVE SPECIES	Tree	13	15.5%	Tree	5	6.0%
84 Total Species	Shrub	2	2.4%	Shrub	7	8.3%
1.8 NATIVE MEAN C	W-Vine	0	0.0%	W-Vine	0	0.0%
0.8 W/Adventives	H-Vine	1	1.2%	H-Vine	0	0.0%
11.0 NATIVE FQI	P-Forb	14	16.7%	P-Forb	12	14.3%
7.3 W/Adventives	B-Forb	0	0.0%	B-Forb	7	8.3%
1.4 NATIVE MEAN W	A-Forb	4	4.8%	A-Forb	6	7.1%
2.3 W/Adventives	P-Grass	0	0.0%	P-Grass	8	9.5%
AVG: Faculative (-)	A-Grass	3	3.6%	A-Grass	2	2.4%
	P-Sedge	0	0.0%	P-Sedge	0	0.0%
	A-Sedge	0	0.0%	A-Sedge	0	0.0%
	Cryptogam	0	0.0%			

## SECTION 2. SPECIES INVENTORY

C SCIENTIFIC NAME	W WETNESS	PHYSIOGNOMY	COMMON NAME
0 ABUTILON THEOPHRASTI	4 FACU-	Ad A-FORB	VELVETLEAF
0 Acer negundo	-2 FACW-	Nt TREE	BOX ELDER
0 Acer saccharinum	-3 FACW	Nt TREE	SILVER MAPLE
0 ACHILLEA MILLEFOLIUM	3 FACU	Ad P-FORB	YARROW
2 Agrimonia gryposepala	2 FACU+	Nt P-FORB	TALL AGRIMONY
0 AGROPYRON REPENS	3 FACU	Ad P-GRASS	QUACK GRASS
0 ALLIARIA PETIOLATA	0 FAC	Ad B-FORB	GARLIC MUSTARD
0 Ambrosia artemisiifolia elatior	3 FACU	Nt A-FORB	COMMON RAGWEED
0 ARCTIUM MINUS	5 UPL	Ad B-FORB	COMMON BURDOCK
1 Asclepias verticillata	5 UPL	Nt P-FORB	WHORLED MILKWEED
4 Aster lateriflorus	-2 FACW-	Nt P-FORB	SIDE-FLOWERING ASTER
0 Aster pilosus	2 FACU+	Nt P-FORB	HAIRY ASTER
2 Aster sagittifolius drummondii	3 [FACU]	Nt P-FORB	DRUMMOND'S ASTER
0 ATRIPLEX PATULA	-2 FACW-	Ad A-FORB	COMMON ORACH
0 BRASSICA NIGRA	5 UPL	Ad A-FORB	BLACK MUSTARD
0 BROMUS INERMIS	5 UPL	Ad P-GRASS	HUNGARIAN BROME
0 CHENOPODIUM ALBUM	1 FAC-	Ad A-FORB	LAMB'S QUARTERS
0 CICHORIUM INTYBUS	5 UPL	Ad P-FORB	CHICORY
0 CIRSIUM ARVENSE	5 UPL	Ad P-FORB	FIELD THISTLE
0 CIRSIUM VULGARE	4 FACU-	Ad B-FORB	BULL THISTLE
0 CONVULVULUS ARVENSIS	5 UPL	Ad P-FORB	FIELD BINDWEED
1 Cornus racemosa	-2 FACW-	Nt SHRUB	GRAY DOGWOOD
0 CORONILLA VARIA	5 UPL	Ad P-FORB	CROWN VETCH
4 Crataegus coccinea	5 UPL	Nt TREE	SCARLET HAWTHORN
2 Crataegus crus-galli	0 FAC	Nt TREE	COCKSPUR HAWTHORN
0 DACTYLIS GLOMERATA	3 FACU	Ad P-GRASS	ORCHARD GRASS
0 Echinochloa crusgalli	-3 FACW	Nt A-GRASS	BARNYARD GRASS
0 ELAEAGNUS UMBELLATA	5 UPL	Ad SHRUB	AUTUMN OLIVE
0 Eragrostis pectinacea	0 FAC	Nt A-GRASS	SMALL LOVE GRASS
0 Eupatorium altissimum	3 [FACU]	Nt P-FORB	TALL BONESET
0 FESTUCA ELATIOR	2 FACU+	Ad P-GRASS	TALL FESCUE
5 Fraxinus americana	3 FACU	Nt TREE	WHITE ASH
1 Fraxinus pennsylvanica subintegerrima	0 FAC	Nt TREE	GREEN ASH
1 Geum canadense	0 FAC	Nt P-FORB	WOOD AVENS
0 GLECHOMA HEDERACEA	3 FACU	Ad P-FORB	CREeping CHARLIE
2 Gleditsia triacanthos	0 FAC	Nt TREE	HONEY LOCUST
5 Helianthus strumosus	5 UPL	Nt P-FORB	PALE-LEAVED SUNFLOWER
0 HIBISCUS TRIONUM	5 UPL	Ad A-FORB	FLOWER-OF-AN-HOUR
2 Juniperus virginiana crebra	3 FACU	Nt TREE	RED CEDAR
0 LEPIDIUM CAMPESTRE	5 UPL	Ad B-FORB	FIELD CRESS
0 Lepidium virginicum	4 FACU-	Nt A-FORB	COMMON PEPPERCRESS
0 LIGUSTRUM VULGARE	1 FAC-	Ad SHRUB	COMMON PRIVET
0 LOLIUM PERENNE	3 FACU	Ad P-GRASS	PERENNIAL RYE GRASS
0 LONICERA MAACKII	5 UPL	Ad SHRUB	AMUR HONEYSUCKLE

0 LONICERA TATARICA	5 [UPL]	Ad SHRUB	TARTARIAN HONEYSUCKLE
0 LONICERA X BELLA	4 FACU-	Ad SHRUB	SHOWY FLY HONEYSUCKLE
0 MEDICAGO SATIVA	5 UPL	Ad P-FORB	ALFALFA
0 MELILOTUS ALBA	3 FACU	Ad B-FORB	WHITE SWEET CLOVER
0 NEPETA CATARIA	1 FAC-	Ad P-FORB	CATNIP
0 Panicum dichotomiflorum	-2 FACW-	Nt A-GRASS	KNEE GRASS
0 PHALARIS ARUNDINACEA	-4 FACW+	Ad P-GRASS	REED CANARY GRASS
0 PHLEUM PRATENSE	3 FACU	Ad P-GRASS	TIMOTHY
0 Physalis subglabrata	5 UPL	Nt P-FORB	TALL GROUND CHERRY
9 Pinus strobus	3 FACU	Nt TREE	WHITE PINE
0 PINUS SYLVESTRIS	5 UPL	Ad TREE	SCOTCH PINE
0 Plantago rugelii	0 FAC	Nt A-FORB	RED-STALKED PLANTAIN
0 POA PRATENSIS	1 FAC-	Ad P-GRASS	KENTUCKY BLUE GRASS
0 Polygonum pensylvanicum	-4 FACW+	Nt A-FORB	PINKWEED
1 Polygonum scandens	0 FAC	Nt H-VINE	CLIMBING FALSE BUCKWHEAT
0 POPULUS ALBA	5 UPL	Ad TREE	WHITE POPLAR
2 Populus deltoides	-1 FAC+	Nt TREE	EASTERN COTTONWOOD
0 POPULUS NIGRA ITALICA	5 UPL	Ad TREE	LOMBARDY POPLAR
0 Prunella vulgaris lanceolata	3 [FACU]	Nt P-FORB	SELF HEAL
7 Quercus rubra	3 FACU	Nt TREE	RED OAK
0 RHAMNUS CATHARTICA	3 FACU	Ad SHRUB	COMMON BUCKTHORN
1 Rhus glabra	5 UPL	Nt SHRUB	SMOOTH SUMAC
1 Rhus typhina	5 UPL	Nt TREE	STAGHORN SUMAC
0 ROBINIA PSEUDOACACIA	4 FACU-	Ad TREE	BLACK LOCUST
0 ROSA MULTIFLORA	3 FACU	Ad SHRUB	MULTIFLORA ROSE
0 RUMEX CRISPUS	-1 FAC+	Ad P-FORB	CURLY DOCK
0 SETARIA FABERI	2 FACU+	Ad A-GRASS	GIANT FOXTAIL
0 SETARIA GLAUCA	0 FAC	Ad A-GRASS	YELLOW FOXTAIL
1 Solidago altissima	3 FACU	Nt P-FORB	TALL GOLDENROD
1 Solidago canadensis	3 FACU	Nt P-FORB	CANADA GOLDENROD
0 TARAXACUM OFFICINALE	3 FACU	Ad P-FORB	COMMON DANDELION
3 Teucrium canadense	-3 FACW	Nt P-FORB	GERMANDER
0 TRIFOLIUM HYBRIDUM	1 FAC-	Ad P-FORB	ALSIKE CLOVER
0 TRIFOLIUM PRATENSE	5 UPL	Ad P-FORB	RED CLOVER
0 ULMUS PUMILA	5 UPL	Ad TREE	SIBERIAN ELM
4 Ulmus rubra	0 FAC	Nt TREE	SLIPPERY ELM
0 VERBASCUM BLATTARIA	3 FACU	Ad B-FORB	MOTH MULLEIN
0 VERBASCUM THAPSUS	5 UPL	Ad B-FORB	COMMON MULLEIN
5 Verbena urticifolia	5 UPL	Nt P-FORB	HAIRY WHITE VERVAIN
0 XANTHIUM STRUMARIUM	-0 FAC	Ad A-FORB	COCKLEBUR

B



**Appendix B**  
**Thickness of Soil Cover - Details**

Plot Date: 11/9/99

File: Z:\1252\008\mwdwgs\00805046A.dwg

Job No. 1252008



# LEGEND

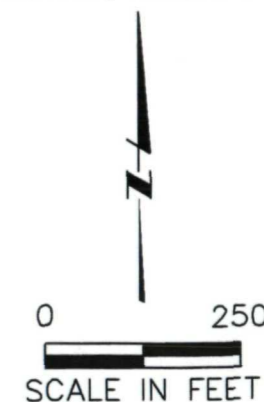
- MH-6 MANHOLE LOCATION AND NUMBER WITH LIQUID CUTOFF TRENCH AND PIPE
- EW01 LEACHATE EXTRACTION WELL/GAS VENT LOCATION AND NUMBER
- LIMITS OF REFUSE BASED ON GEOPHYSICAL TESTING AND SOIL BORINGS
- LS1 LIFT STATION LOCATION AND NUMBER
- LEACHATE PRESSURE CONVEYANCE PIPE AND CONTROL WIRE
- LEACHATE GRAVITY CONVEYANCE PIPE AND DIRECTION
- GAS HEADER PIPE, LENGTH, SLOPE AND DIRECTION
- DL01 DRIPLEG LOCATION AND NUMBER
- ROOT EXCAVATION
- THICKNESS OF SOIL COVER OVER THE CLAY CAP
  - < 1 FT (OR UNMAPPED)
  - >= 1 FT < 2 FT
  - >= 2 FT
- UNITS DEFINED DURING SEPTEMBER 1999 SITE RECONNAISSANCE

AREA 1 OCTOBER 1998 SITE RECONNAISSANCE

unit 1 SEPTEMBER 1999 SITE RECONNAISSANCE

## NOTES

1. APPROXIMATE LIMITS OF REFUSE HAVE BEEN ESTIMATED BASED ON INFORMATION PRESENTED IN THE PREDESIGN REPORT, APRIL 1997.
2. COVER MATERIALS WERE MAPPED USING SOIL BORING DATA WAS COMPILED FROM THE FOLLOWING SOURCES:
  - TESTING SERVICE CORPORATION, CAROL STREAM, ILLINOIS, "BLACKWELL FOREST PRESERVE DEEP VENTS AND EXPLORATORY BORINGS," OCTOBER 1, 1986.
  - MONTGOMERY WATSON, ADDISON, ILLINOIS, "REVISED PREDESIGN REPORT," JULY 1997.
  - MONTGOMERY WATSON, ADDISON, ILLINOIS, "PREDESIGN INVESTIGATION," DECEMBER 1996.



REV	DATE	BY	DESCRIPTION

SCALE  
AS SHOWN

DESIGNED  
DRAWN  
CHECKED

SUBMITTED BY:  
(PROJECT MANAGER) DATE  
(PROJECT ENGINEER) LICENSE NO. DATE



**MONTGOMERY WATSON**  
Chicago, Illinois

BLACKWELL LANDFILL NPL SITE  
DU PAGE COUNTY, ILLINOIS

THICKNESS OF SOIL COVER

APPENDIX  
B



**Appendix C**  
**Deed Restrictions**

RECEIPT FOR PAYMENT

**J.P. "RICK" CARNEY**

***DuPage County Recorder***

421 NORTH COUNTY FARM ROAD - WHEATON, IL 60187

(708) 682-7200

RECEIPT NO.: 9708050162 SD

RECEIVED OF: DU PAGE COUNTY FOREST PRESERVE

DATE: 08/05/97

RECORDINGS : \$0.00 JERRY

\* FEES WAIVED \* \$0.00

RECEIVED FOR DOCUMENTS NUMBERED:

FROM: 114214 TO: 114214

DUPAGE COUNTY RECORDER - "SERVING YOU"

ORDINANCE NO.97-263

ORDINANCE APPROVING SUBMITTAL OF A DECLARATION OF DEED  
RESTRICTIONS AND RESTRICTIVE COVENANTS (DEED RESTRICTIONS) UPON  
REAL ESTATE TO THE DU PAGE COUNTY RECORDER OF DEEDS AS REQUIRED BY  
THE ADMINISTRATIVE ORDER BY CONSENT IN CONNECTION WITH THE DU PAGE  
COUNTY LANDFILL/BLACKWELL FOREST PRESERVE PROPERTY LOCATED  
WITHIN THE BLACKWELL FOREST PRESERVE

---

WHEREAS, the Forest Preserve District of DuPage County, Illinois (hereinafter the "District") is the owner of the Roy C. Blackwell Forest Preserve in Warrenville, Illinois; and

WHEREAS, from 1965 through 1973 the District as owner of and the Public Works Department of the county of DuPage as operator operated a municipal landfill on approximately 40 acres of land at the Roy C. Blackwell Forest Preserve; and

WHEREAS, a recreational hill was constructed through the use of sanitary landfill techniques known as Mt. Hoy, which hill was completed in 1973; and

WHEREAS, on February 20, 1996, the District Ordinance #96-062 authorized the signing and transmittal to USEPA of a new Administrative Order by Consent, which provided among other things, that the Respondent be required to conduct response actions described therein to abate an imminent and substantial endangerment to the public health, welfare or the environment which may be presented by the actual or threatened release of hazardous substances at or from the Site; and

WHEREAS, in conjunction with these response actions the District is required to file with the DuPage County Recorder certain Deed Restrictions upon the landfill area; and

WHEREAS, it is in the best interests of the District to approve the Deed Restrictions and authorize its execution on behalf of the District.

NOW, THEREFORE, BE IT ORDAINED by the President and Commissioners of the Forest Preserve District of DuPage County, Illinois:

- A. That the District hereby approves the Deed Restrictions for the Blackwell Forest Preserve, a copy of which is attached hereto and made a part hereof.
- B. The President and secretary of the District are authorized and directed to execute and transmit the original signed Deed Restrictions to the DuPage County Recorder, on behalf of the District.
- C. The Secretary of the District is authorized and directed to transmit a copy of this Ordinance to the Executive Director, Secretary, Finance Officer, Attorney and the Director of Environmental Services of the Forest Preserve District of DuPage County, respectively.

PASSED AND APPROVED by the President and Board of Commissioners of the Forest Preserve District of DuPage County, Illinois this \_\_\_\_\_ day of \_\_\_\_\_ 1997.

APPROVED:

\_\_\_\_\_  
President

\_\_\_\_\_  
Secretary

A DECLARATION OF DEED RESTRICTIONS AND RESTRICTIVE COVENANTS (DEED  
RESTRICTIONS) UPON REAL ESTATE TO THE DU PAGE COUNTY RECORDER OF DEEDS  
AS REQUIRED BY THE ADMINISTRATIVE ORDER BY CONSENT IN CONNECTION WITH  
THE DU PAGE COUNTY LANDFILL/BLACKWELL FOREST PRESERVE PROPERTY LOCATED  
WITHIN THE BLACKWELL FOREST PRESERVE.

## DECLARATION OF DEED RESTRICTIONS AND RESTRICTIVE COVENANTS UPON REAL ESTATE

The Forest Preserve District of DuPage County, owner of the real estate described below, hereby impose restrictions on that portion of the described real estate which is known as the DuPage County Landfill/Blackwell Forest Preserve, (hereinafter "the Site") within the Blackwell Forest Preserve, in Section 26, Township 39 North, Range 9 East, DuPage County, Illinois:

THAT PART OF THE SOUTHEAST QUARTER AND OF THE SOUTHWEST QUARTER OF SECTION 26, TOWNSHIP 39 NORTH, RANGE 9 EAST OF THE THIRD PRINCIPAL MERIDIAN, DESCRIBED BY COMMENCING AT THE SOUTHEAST CORNER OF SAID SOUTHWEST QUARTER AND RUNNING THENCE NORTH 0 DEGREES 30 MINUTES 46 SECONDS WEST ALONG THE EAST LINE OF SAID SOUTHWEST QUARTER, 1365.89 FEET FOR A PLACE OF BEGINNING; THENCE SOUTH 82 DEGREES 02 MINUTES 18 SECONDS WEST, 271.76 FEET; THENCE SOUTH 86 DEGREES 47 MINUTES 00 SECONDS WEST, 516.81 FEET; THENCE SOUTH 74 DEGREES 01 MINUTE 25 SECONDS WEST, 508.65 FEET; THENCE NORTH 70 DEGREES 41 MINUTES 00 SECONDS WEST, 308.36 FEET; THENCE NORTH 21 DEGREES 13 MINUTES 25 SECONDS WEST, 220.99 FEET; THENCE NORTH 1 DEGREE 29 MINUTES 15 SECONDS WEST, 154.05 FEET; THENCE NORTH 25 DEGREES 44 MINUTES 27 SECONDS EAST, 186.51 FEET; THENCE NORTH 55 DEGREES 11 MINUTES 40 SECONDS EAST, 327.61 FEET; THENCE NORTH 23 DEGREES 56 MINUTES 10 SECONDS WEST, 438.73 FEET; THENCE NORTH 25 DEGREES 57 MINUTES 50 SECONDS EAST, 127.91 FEET; THENCE NORTH 53 DEGREES 48 MINUTES 55 SECONDS EAST, 267.62 FEET; THENCE NORTH 89 DEGREES 06 MINUTES 17 SECONDS EAST, 512.06 FEET; THENCE SOUTH 6 DEGREES 22 MINUTES 08 SECONDS WEST, 441.73 FEET; THENCE SOUTH 56 DEGREES 13 MINUTES 58 SECONDS EAST, 824.01 FEET; THENCE SOUTH 10 DEGREES 39 MINUTES 50 SECONDS EAST, 399.91 FEET; THENCE SOUTH 82 DEGREES 02 MINUTES 18 SECONDS WEST, 17.02 FEET TO THE PLACE OF BEGINNING, IN WINFIELD TOWNSHIP, DU PAGE COUNTY, ILLINOIS, containing 35.25 acres.

As depicted on the attached map prepared by Montgomery Watson, drawing 1252008/04090040.

The following restrictions are imposed upon the Site, its present and any future owner (including heirs to the above described real estate), their authorized agents, assigns, employees, or persons acting under their direction or control, for the purposes of protecting public health or welfare or the environment, preventing interference with the performance, and maintenance, of any response actions selected and/or undertaken by the United States Environmental Protection Agency ("U.S. EPA"), or any party acting as an agent for the U.S. EPA, pursuant to Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"). Specifically, the following deed restrictions shall apply to the Site:

1. There shall be no use of, or activity at, the Site that may interfere with, damage, or otherwise impair the effectiveness of any response action (or component thereof) selected and/or undertaken by U.S. EPA, or any party acting as agent for U.S. EPA, pursuant to Section 104 of CERCLA, except with written approval of U.S. EPA, and consistent with all statutory and regulatory requirements;
2. There shall be no consumptive, extractive, or other use of the groundwater underlying the Site that could cause exposure of humans or animals to the groundwater underlying the Site. In addition, there shall be no installation of drinking water production wells on the Site, except as approved in writing by U.S. EPA;

3. There shall be no residential, commercial, or agricultural use of the landfill, including, but not limited to, any on-site excavation, landfilling, mining, invasive construction, and drilling, except as approved in writing by U.S. EPA;
4. There shall be no tampering with, or removal of, the containment or monitoring systems that remain on the Site as a result of implementation of any response action by U.S. EPA, or any party acting as agent for U.S. EPA, and which is selected and/or undertaken by U.S. EPA pursuant to Section 104 of CERCLA;
5. There shall be no activities that cause destruction of vegetation on the landfill or otherwise could result in degradation of the remedial components; and
6. There shall be no ignition sources on the landfill except as approved, in writing by U.S. EPA.

The obligation to implement and maintain the above restrictions shall run with that portion of the land that is described as the Site and shall remain in effect until such time as U.S. EPA provides to the landowner a written certification stating the above restrictions are no longer necessary.

IN WITNESS WHEREOF, has caused these Deed Restrictions to be executed this  
5th day of August m 1997.

Respondent Landowner: \_\_\_\_\_

Address \_\_\_\_\_

FOREST PRESERVE DISTRICT OF DUPAGE COUNTY

185 Spring Ave., Glen Ellyn, IL 60137

STATE OF ILLINOIS )

ss:

COUNTY OF DUPAGE )

Before me, the undersigned, a Notary Public in and for said County and State, this  
5th day of AUGUST, 1997, personally appeared \_\_\_\_\_,  
 and acknowledged this instrument.

Notary Public

My commission expires \_\_\_\_\_

"OFFICIAL SEAL"

Jerome C. Hartwig

Notary Public, State of Illinois

My Commission Expires 02/29/00

# *Steinbrecher Land Surveyors, Inc.*

Professional Land Surveying and Professional Civil Engineering

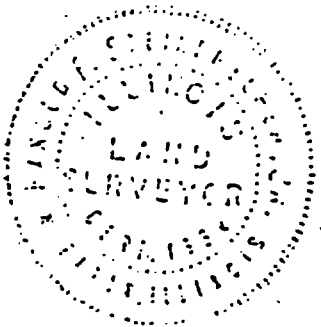
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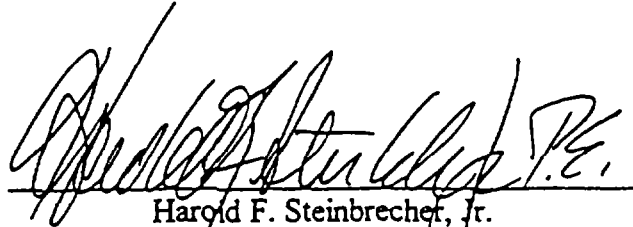
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STATE OF ILLINOIS   )  
                                  (   ss.  
COUNTY OF DUPAGE )

This is to certify that I, Harold F. Steinbrecher, Jr., a Professional Land Surveyor, have prepared a certain legal description of a certain tract shown on a map prepared by Montgomery Watson, drawing 1252008/04090040, and have related same to government survey lines by actual field measurement.

West Chicago, IL.,   July 23, 1997



  
Harold F. Steinbrecher, Jr.  
Professional Land Surveyor 1594